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The Acoustic Model Evaluation Committee (AMEC) Reports

Volume III, Appendices E-H

Evaluation of the RAYMODE X Propagation Loss Model (U)

Prepared by

Richard B. Lauer, NORDA
Numerical Modeling Division

Including

The Physics of RAYMODE X (U)
by Roy Deavenport, NUSC
New London, Connecticut

September 1982

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Appendix IIIE. Accuracy Assessment of RAYMODE X Compared to Lorad Experimental Data (U)

Lorad (U)

Environment (U)

(C) The sound speed profile selected for model runs (Martin, 1982) consists of the merge between an average near surface profile (to 150 m) and a Nansen cast taken about one month after the experiment. The upper 150 m of the profile was the result of averaging three bathythermograph records, one at the receiver and two at a distance of one convergence zone (CZ). Sound speeds were originally calculated from equations fit by Mackenzie to tables of Kuwahara. These were later corrected to Wilson's equation. The sound speed is plotted and tabulated in Figure IIIE-1. A surface duct is found to a depth of 30.5 m overlying a deep sound channel with axis at 750 m. The profile has a positive depth excess of 975 m and intersects the bottom at 5670 m.

(C) The bottom class is MGS Type 7. Bottom loss versus grazing angle is listed in Table IIIE-1 and plotted in Figure IIIE-2. At 0° the loss is 16.7 dB, which increases to 17.2 dB at 15°. The maximum bottom loss of 19.0 dB is found at 73° and the loss at normal incidence in 18.9 dB.

Test Cases (U)

(C) Two test cases, each consisting of seven subsets were selected for use in model evaluation. The LORAD experimental data for Cases IA through IIG are shown in Figures IIIE-3 through IIIE-16.

Case	Run Number	Frequency (Hz)	Source Depth (m)	Receiver Depth (m)	Bottom Bounce Region	Convergence Zone
IA	35	530	15.2	30.5	First	First
IB	65	530	15.2	30.5	Second	Second
IC	85	530	15.2	30.5	-	Third
ID	105	530	15.2	30.5	-	Fourth
IE	125	530	15.2	30.5	-	Fifth
IF	145	530	15.2	30.5	-	Sixth
IG	165	530	15.2	30.5	-	Seventh
IIA	3D	530	15.2	304.8	First	First
IIB	6D	530	15.2	304.8	Second	Second
IIC	8D	530	15.2	304.8	-	Third
IID	10D	530	15.2	304.8	-	Fourth
IIE	12D	530	15.2	304.8	-	Fifth
IIF	14D	530	15.2	304.8	-	Sixth
IIG	16D	530	15.2	304.8	-	Seventh

Accuracy Assessment Results (U)

(C) The accuracy assessment procedures were followed as outlined in section 1.1 and as described in detail in section 5 of Volume I of this series. We note at this point that the maximum range (440 km) of the LORAD data coupled with its high data density necessitated three model runs to capture the entire range extent (0-150 km, 150-300 km, 300-440 km). These three runs consisted of 300, 300, and 280 points yielding a point every 0.5 km over the full range. Two features of the RAYMODE X model made this possible: (1) independent selection of start range and range increment and (2) the maximum number of points dimensioned to 400 points.

(U) The following plots are given for each of the fourteen LORAD cases: (a) RAYMODE X output using the coherent phase addition option, (b) coherent RAYMODE X output smoothed by application of a 2 km sliding average, (c) smoothed coherent RAYMODE X output subtracted from LORAD experimental data, (d) RAYMODE X output using the incoherent phase addition option, (e) incoherent RAYMODE X output subtracted from LORAD experimental data. Those plots are presented in Figures IIIE-17-86.

(C) Means and standard deviations of the differences between RAYMODE X and the LORAD data are given in each case in Table IIIE-2. A positive mean value indicates lower propagation loss for RAYMODE X than for LORAD data, and the model prediction is therefore optimistic with respect to the experimental result. For this situation, detection ranges as predicted by the model are greater than those indicated by the experimental data. For a negative mean value the converse of the above holds. We shall now examine the differences between the RAYMODE and LORAD results by the "Difference Method." The reader is encouraged to refer to Table IIIE-2 and the appropriate figures while reading the following text. We recall that Cases IA-IG apply to a receiver at the surface duct boundary of 30.5 m (100 feet) and Cases IIA-IIG apply to a receiver at 305 m (1000 feet). For Case IA in the bottom bounce region, the LORAD data successively shows less loss, greater loss, and less loss again compared to RAYMODE X as range increases. Only between 5 and 15 km and then between 40 and 52 km is there basic agreement in the bottom bounce region. It would appear that from the nature of the disagreement, a change in MGS bottom loss type would not result in a significantly better difference curve. The RAYMODE X first convergence zone is broader than LORAD's, the primary effect being onset at shorter range. The RAYMODE CZ is double-lobed; LORAD's CZ is single lobed. The higher bottom loss of LORAD in the area of the first CZ (as compared to the bottom loss of RAYMODE before and after the CZ) permits the observation of the CZ to propagation loss values greater than 100 dB. For Case IB, there is fair agreement between LORAD and RAYMODE in the second bottom bounce region to 75 km, particularly for the incoherent option. From 75 to 90 km, the experimental data shows greater loss than the model. From 90 to 110 km, LORAD and RAYMODE are in basic agreement. From 110 km to the onset of the second convergence zone at about 120 km, RAYMODE shows an average of 12 dB less loss than the LORAD data. In the second, as in the first bottom bounce region, the nature of the differences between the LORAD data and RAYMODE predictions could not be greatly improved by a change in MGS bottom loss type. The second convergence zone as predicted by RAYMODE X may be in good agreement with that of the LORAD data but it is difficult to tell due to some unusual features of the LORAD data at the start of the zone and a low data density at the end of the CZ. In Case IC, the start of the third convergence zone is steeper for RAYMODE X than for LORAD. Aside from this, shape and duration of the third CZ are roughly equal. The level of fluctuations in the LORAD data and in the unsmoothed RAYMODE X coherent output are approximately the same. LORAD shows a double-lobed CZ; the RAYMODE coherent CZ

is multi-lobed and the incoherent CZ is basically double-lobed. For Case ID, the fourth convergence zone onset is earlier for LORAD than for RAYMODE. Aside from this, however, the two are in basic agreement and any differences are due to fluctuations within the LORAD convergence zone. For Case IE, the CZ start has a steeper slope for RAYMODE than for LORAD. Aside from this difference, the LORAD data and RAYMODE prediction are in agreement with respect to CZ shape and duration. The LORAD fifth CZ does, however, show more scatter than does RAYMODE. For Case IF, the envelopes of the LORAD and JOAST sixth convergence zone are almost identical from 360 to 382 km; the LORAD CZ does however extend about 2 km beyond RAYMODE's. The RAYMODE X coherent result shows maximum fluctuations of 10 dB; LORAD data has fluctuations as large as 15-20 dB. Case IG gives the seventh convergence zone. The CZ start for LORAD precedes that of RAYMODE X by about 3 km. The low loss envelope of the LORAD data agrees with the RAYMODE CZ. The LORAD CZ shows far more fluctuation in the CZ than does RAYMODE. The CZ end for LORAD and RAYMODE X coherent are in close agreement. The RAYMODE incoherent curve does not indicate a CZ end at the greatest range (440 km) for which calculations were made.

(C) We now turn to the deep receiver at 1000 feet (305 m); For Case IIA, the RAYMODE X predictions are pessimistic (i.e., show higher propagation loss) compared to LORAD data in the first bottom bounce region. Displacement of 10 dB would bring close agreement in this region to a range of about 50 km. Between 50 km and the onset of the first CZ the curves would be better left unshifted. The onset of the first CZ for RAYMODE precedes LORAD's by about 2 km. This also holds for the placement of the notch in the double-lobed convergence zone. The CZs have nearly identical end ranges. For Case IIB (as was true in the first bottom bounce region), a shift of the model by 10 dB to lower propagation loss would bring RAYMODE X predictions and LORAD data into basic agreement in the second bottom bounce region. The RAYMODE second convergence zone has a steeper slope at onset than does LORAD. Beyond this the two CZs are in general agreement. The third convergence zones are given in Case IIC. The RAYMODE result shows a steeper CZ onset at greater range than does LORAD data. Beyond this, the LORAD and RAYMODE convergence zone are in rather close agreement, the primary difference being a greater scatter in the LORAD data. In Case IID, the fourth convergence zone is only partially defined by the LORAD data which does not extend to zones end. We have become accustomed to seeing the LORAD CZ onset precede that of RAYMODE and rise more gently; the fourth CZ does not belie this expectation. Also as usual, past the start, agreement is achieved between the LORAD and RAYMODE convergence zones. For this case, the extent of fluctuations is roughly the same for model and experimental data. In Case IIE, once again the CZ start for LORAD precedes that of RAYMODE and is less steep. Beyond this, basic agreement is found, particularly regarding the CZ end. LORAD data shows greater fluctuation than coherent RAYMODE predictions, especially in the first half of the CZ. In the sixth convergence zone, shown in Case IIF results, once again the LORAD CZ precedes that of RAYMODE X and rises more gently. Beyond this agreement in shape is basically found although the LORAD low-loss envelope is about 2-3 dB above RAYMODE's. The CZ ends of LORAD and RAYMODE are in agreement. The extent of fluctuations is roughly the same for LORAD and RAYMODE. In Case IIG, we have the seventh convergence zone, although the LORAD data does not extend to the end of the CZ. The CZ start for LORAD precedes that of RAYMODE X by about 8 km. Both LORAD and RAYMODE basically agree in level in the CZ. The LORAD data shows slightly more fluctuation within the zone.

(C) Detection ranges for LORAD experimental data and RAYMODE X predictions as a function of figure of merit (FOM) are given in Tables IIIE-3 through IIIE-16

for Cases IA through IIG. Since the LORAD data and RAYMODE X predictions often are characterized by fluctuations the concept of zonal detection coverage (ZDC) is introduced. ZDC is given as a percentage of the data points in a given range interval, the propagation loss of which is less than a stated figure of merit. This corresponds to the percentage of opportunities for which detection can be made on a single look basis. In Case IA, the LORAD data is seen to give much greater detection coverage than RAYMODE predictions for FOM $\leq$ 100 dB in the first bottom bounce region. For FOM = 105 dB, RAYMODE coherent gives less coverage than LORAD data while RAYMODE incoherent predicts more in the first bottom bounce region. The first CZ start is seen to occur about 2 km earlier for RAYMODE predictions than for LORAD data. The end of the CZ is essentially the same for LORAD and RAYMODE for FOM $\leq$ 90 dB. For FOM $\geq$ 95 dB, the LORAD CZ ends at about 2 km shorter range than does RAYMODE's. For FOM $\geq$ 95 dB, the start of the CZ is hidden by bottom bounce energy for RAYMODE. In Case IB, neither LORAD nor RAYMODE give any detection coverage in the second bottom bounce region at FOM $\leq$ 95 dB. LORAD has no coverage at FOM = 100 dB in the second bottom bounce region while RAYMODE shows intermittent coverage for the coherent phase option and no coverage for the incoherent result. For FOMs of 105 and 110 dB, RAYMODE shows less complete coverage than LORAD but at a higher zonal detection coverage percentage. For the second convergence zone, RAYMODE's CZ onset precedes LORAD's by 1.5-2 km for FOM $\leq$ 95 dB. For FOM = 100 dB, LORAD precedes RAYMODE's CZ onset by 1 km The CZ end for LORAD and RAYMODE coherent agree well; RAYMODE incoherent has a CZ end which precedes these at most FOMs. Case IC shows for the third CZ start that RAYMODE precedes LORAD by distances varying from 3 km at FOM = 85 dB to 1 km at FOM = 105 dB. For FOM $\leq$ 95 dB, the RAYMODE incoherent CZ ends about 2 km shorter than does the LORAD or RAYMODE coherent CZs. For FOM $\geq$ 100 dB, model and experiment agree with regard to CZ end. The fourth convergence zone (Case ID) starts 1.5 to 4 km sooner for LORAD than for RAYMODE, the disparity increasing with increasing figure of merit. The CZ ends are approximately equal for FOM $\geq$ 95 dB; at FOM = 90 dB; however, the LORAD CZ extends to longer range than that of RAYMODE (by 2 km for coherent result and 6.5 km for the incoherent result). In the fifth convergence zone (Case IE) the start for RAYMODE precedes that of LORAD by 4 to 2 km for FOMs ranging from 90 dB to 100 dB, respectively. At FOM = 105 dB, the CZ start ranges are roughly equal. The CZ end for LORAD is generally 1 km beyond RAYMODE coherent regardless of FOM and 4.5 to 6.5 km beyond RAYMODE incoherent for FOM = 95 and 90 dB, respectively. For FOM $\geq$ 100 dB, RAYMODE incoherent and LORAD have CZ ends at the same range. For Case IF, the CZ start ranges for LORAD and RAYMODE are roughly equal, regardless of FOM. The LORAD CZ ends at greater range than RAYMODE by increasingly greater amounts as FOM increases. The incoherent phase result is a poorer predictor of LORAD's CZ end than the coherent result (predicting shorter end ranges by as much as 7 km). For the seventh convergence zone (Case IG), LORAD's start precedes RAYMODE's by 1 to 5 km, the worst agreement at the highest FOM of 110 dB. The LORAD CZ end is ill-defined in this case so no comparison with RAYMODE results is made.

(C) For Case IIA, detection coverage in the first bottom bounce region is better for RAYMODE than for LORAD for FOM $\leq$ 105 dB, the discrepancy being greatest at lowest FOMs. At FOM = 110 dB, both model and experiment give essentially continuous coverage (but at a greater ZDC percentage for RAYMODE). First convergence zone start and end ranges are in basic agreement, although the agreement in start ranges is predicated on some uncertain interpolation of LORAD data. For Case IIB, there is no coverage in the second bottom bounce region for RAYMODE until FOM = 115 dB for which there is limited coverage; LORAD coverage in the second bottom bounce region starts at

FOM = 105 dB. At FOM = 115 dB, LORAD coverage is far more extensive than RAYMODE's in the second bottom bounce region. The second CZ start for LORAD is at somewhat greater range than RAYMODE's at FOM = 90 dB, at equal range at FOM = 95 dB, and at somewhat shorter range for FOM ≥ 100 dB. The CZ ends for LORAD and RAYMODE are approximately equal for FOM ≥ 95 dB. At FOM = 90 dB the LORAD CZ end is at 2.5 km greater range than RAYMODE's. For the third convergence zone (Case IIC), the start ranges for LORAD are greater than are RAYMODE's for FOM = 90 and 95 dB and shorter for FOM ≥ 100 dB. The end ranges for LORAD are 4–6 km greater in range than are the end ranges for RAYMODE X. For Case IID, the start of the fourth convergence zone occurs at shorter range for LORAD data than for RAYMODE X predictions, from 1 km at FOM = 95 dB to 7 km at FOM = 110 dB. Since the LORAD data does not include the end of the fourth CZ, no comparison with RAYMODE predictions can be made. For the fifth convergence zone (Case IIE), LORAD's CZ is broader than RAYMODE's CZ. LORAD's CZ starts 2 to 10 km before RAYMODE's as FOM increases from 100 to 110 dB. LORAD's CZ end is at greater range than the RAYMODE X coherent prediction by 3.5 to 1 km and at greater range than the RAYMODE X incoherent prediction by 9.5 to 2.5 km as FOM goes from 100 to 110 dB. For the sixth CZ (Case IIF) the CZ start for LORAD data was at 8 km shorter range than for RAYMODE. LORAD and RAYMODE sixth CZ ends were the same for FOM = 110 dB, but for FOM = 105 dB the LORAD CZ ended at greater range than did RAYMODE's (2 km for the coherent result and 4 km for the incoherent result). For the seventh CZ (Case IIG) the end of the zone for the LORAD data is ill-defined and therefore comparison with RAYMODE X is possible for only CZ start. LORAD's CZ start precedes RAYMODE's by 5.5 km at FOM = 105 dB and 8.5 km for FOM = 110 dB.

General Conclusions (U)

(C) Cases IA–IG for which the source is in the surface duct and the receiver at the duct limit of 100 feet (30.5 m): (A1) LORAD shows somewhat better detection coverage than RAYMODE X in the bottom bounce regions. Changing the MGS bottom class in the model should not provide significant improvement since the shapes of the propagation loss versus range curves for LORAD and RAYMODE are different in the bottom bounce regions. (B1) The LORAD first convergence zone has one lobe whereas RAYMODE X's has two. (C1) The LORAD CZ start precedes RAYMODE's in the first, third, and fifth CZs, and the converse is true for the second, fourth and seventh CZs. (D1) The ends of the LORAD CZs occur at equal or greater ranges than RAYMODE's. (E1) Fluctuations in the convergence zones are greater for LORAD data than for RAYMODE predictions. (F1) The RAYMODE X coherent results are in better agreement with LORAD data than are RAYMODE X incoherent results.

(C) Cases IIA–IIG for which the source is in the surface duct and the receiver is below the duct at 1000 feet (305 m): (A2) LORAD data and RAYMODE predictions differ by about 10 dB in bottom bounce regions with LORAD showing less propagation loss. The use of lower bottom loss as model input would lead to better agreement. (B2) The start and end ranges for LORAD and RAYMODE agree for the first and second convergence zones (averaging over all figures of merit). The first CZ is double-lobed for both model and experimental data. (C2) From the third CZ on, the start of the LORAD CZ precedes that of RAYMODE and the model's CZ start is steeper than that indicated by the experimental data. Range disparities as great as 10 km are found in CZ start range between LORAD and RAYMODE. (D2) The range at which the convergence zone ends for LORAD data is equal to or greater than that for RAYMODE by as much as 6 km. (E2) Fluctuations in the LORAD data are of roughly the same magnitude as the unsmoothed RAYMODE coherent output. (F2) The RAYMODE X coherent prediction is in generally better agreement with the LORAD data than the RAYMODE X incoherent prediction.

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(C) Table IIIE-1. Bottom Loss (dB) versus Grazing Angle (degrees). MGS Type 7. Frequency = 530 Hertz.

Θ	BL	Θ	BL	Θ	BL	Θ	BL	Θ	BL	Θ	BL
0	16.66	15	17.19	30	13.10	45	18.66	60	18.94	75	19.01
1	16.66	16	17.26	31	18.15	46	18.68	61	18.95	76	19.01
2	16.66	17	17.33	32	18.19	47	18.71	62	18.96	77	19.01
3	16.66	18	17.40	33	18.24	48	18.73	63	18.97	78	19.01
4	16.66	19	17.47	34	18.28	49	18.76	64	18.98	79	19.00
5	16.66	20	17.54	35	18.32	50	18.78	65	18.99	80	19.00
6	16.66	21	17.60	36	18.36	51	18.80	66	18.99	81	18.99
7	16.66	22	17.66	37	18.40	52	18.82	67	19.00	82	18.98
8	16.66	23	17.73	38	18.44	53	18.84	68	19.00	83	18.97
9	16.70	24	17.78	39	18.47	54	18.86	69	19.01	84	18.97
10	16.78	25	17.84	40	18.51	55	18.87	70	19.01	85	18.96
11	16.87	26	17.90	41	18.54	56	18.89	71	19.01	86	18.95
12	16.97	27	17.95	42	18.57	57	18.90	72	19.01	87	18.94
13	17.03	28	18.00	43	18.60	58	18.92	73	19.02	88	18.92
14	17.11	29	18.05	44	18.63	59	18.93	74	19.01	89	18.91

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(C) Table IIIE-2. Means (μ) and Standard Deviations (σ) in dB of Differences Obtained by Subtracting RAYMODE X Coherent[1] and Incoherent Results from LORAD Experimental Data.

Case	Run No.	Frequency (Hertz)	Source Depth (m)	Receiver Depth (m)	Minimum Range (km)	Maximum Range (km)	Coherent		Incoherent	
							μ	σ	μ	σ
IA	3S	530	15.2	30.5	1.8	73.2	0.2	6.4	0.1	5.4
IB	6S	530	15.2	30.5	41.7	132.5	5.8	7.7	4.5	7.5
IC	8S	530	15.2	30.5	168.3	200.3	1.3	3.5	2.9	3.6
ID	10S	530	15.2	30.5	233.5	254.1	0.5	3.1	0.2	3.3
IE	12S	530	15.2	30.5	299.4	323.7	0.2	2.8	0.3	2.8
IF	14S	530	15.2	30.5	357.0	385.8	0.2	5.3	0.3	2.4
IG	16S	530	15.2	30.5	414.6	440.1	2.1	6.6	2.6	6.5
IIA	3D	530	15.2	304.8	2.8	70.6	-3.1	6.1	-2.2	5.0
IIB	6D	530	15.2	304.8	41.7	132.5	-2.9	8.8	-1.9	8.3
IIC	8D	530	15.2	304.8	173.1	198.9	-0.9	4.1	-0.7	3.7
IID	10D	530	15.2	304.8	231.9	249.4	-1.2	4.5	-0.8	4.2
IIE	12D	530	15.2	304.8	290.3	322.7	-1.2	4.2	-1.0	4.1
IIF	14D	530	15.2	304.8	348.0	383.2	-2.1	6.3	-1.9	6.1
IIG	16D	530	15.2	304.8	407.7	440.1	-7.5	9.4	-6.7	10.0

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(C) Table IIIE-3. Detection Range in km as a Function of Figure of Merit (FOM) in dB for LORAD RUN 3S Data (4-75 km) and RAYMODE X Coherent and Incoherent Model Results. Case IA: (Source Depth = 15 m, Receiver Depth = 30 m, Frequency = 530 Hz). Bottom Loss: MGS Type 7.

Data Set	FOM	R_c [1]	First Bottom Bounce Region	1st CZ3 Start	1st CZ3 End
LORAD 3S	80		ZDC[2] 10%, 3-8 km	61.5	63.0
RAYMODE X Coherent	80	4.0		59.0	64.0
RAYMODE X Incoherent	80	4.0		60.0	63.0
LORAD 3S	85		ZDC 50%, 3-8 km	60.5	64.0
RAYMODE X Coherent	85	5.0		59.0	64.5
RAYMODE X Incoherent	85	5.5		59.5	64.0
LORAD 3S	90		ZDC 90%, 3-10 km; ZDC 40%, 10-20 km ZDC 50%, 20-30 km; ZDC 20%, 35-40 km	60.0	64.5
RAYMODE X Coherent	90	9.0	100% coverage 9-11.5 km	58.0	65.0
RAYMODE X Incoherent	90	10.0		59.0	65.0
LORAD 3S	95	10.0	ZDC 80%, 10-30 km; ZDC 50%, 30-41 km ZDC 20%, 41-51 km	60.0	65.0
RAYMODE X Coherent	95	13.0	ZDC 15%, 14-23 km; 100% coverage 49-49.5 km; 51.5-67 km		67.0
RAYMODE X Incoherent	95	15.0	100% coverage, 56.5-66 km		66.0
LORAD 3S	100	32.0	ZDC 85%, 32-42 km; ZDC 50%, 42-50 km ZDC 30%, 50-57 km	59.5	65.0
RAYMODE X Coherent	100	19.0	100% coverage 47.1-69.5 km, 70-71 km. ZDC 45%, 20-43 km		69.5
RAYMODE X Incoherent	100	35.5	100% coverage, 47.5-68.0 km		68.0
LORAD 3S	105	46.0	ZDC 50%, 51-58 km ZDC 90%, 46-51 km	58.0	65.5
RAYMODE X Coherent	105	19.5	ZDC 90%, 20-43.5 km; 100% coverage, 44-86 km		
RAYMODE X Incoherent	105	71.5			

1. R_c = Range to which coverage is continuous.
2. ZDC = Zonal Detection Coverage in percentage of the indicated interval over which detection is possible.
3. Convergence Zone is double lobed to 93 dB for RAYMODE X coherent, 85 dB for RAYMODE X Incoherent.

(C) Table IIIE-4. Detection Range in km as a Function of Figure of Merit (FOM) in dB for LORAD Run 6S (75-132 km) and RAYMODE X Coherent and Incoherent Model Results. Case IB: (Source Depth - 15 m, Receiver Depth = 30 m, Frequency = 530 Hz). Bottom Loss: MGS Type Z.

Data Set	FOM	Second Bottom Bounce Region	2nd CZ[3] Start	2nd CZ[3] End
LORAD 6S	80		123.0	124.0
RAYMODE X Coherent	80		121.0	121.5
RAYMODE X Incoherent	80		121.0	122.5
LORAD 6S	85		122.5	125.5
RAYMODE X Coherent	85		121.0	125.0
RAYMODE X Incoherent	85		120.5	123.0
LORAD 6S	90		122.0	126.0
RAYMODE X Coherent	90		120.5	127.5
RAYMODE X Incoherent	90		120.5	126.0
LORAD 6S	95		121.5	130.0
RAYMODE X Coherent	95		120.0	130.0
RAYMODE X Incoherent	95		120.0	128.0
LORAD 6S	100		119.0	131.5
RAYMODE X Coherent	100	100% coverage 75.5-85 km, 114-117 km 119-119.5 km	120.0	131.0
RAYMODE X Incoherent	100	Coverage 118.5-119 km	120.0	130.5
LORAD 6S	105	ZDC[2] 25%, 75-110 km; 100% coverage, 120->135 km		
RAYMODE X Coherent	105	100% coverage, 72.5-86.5 km, 109-120 km	120.0	131.5
RAYMODE X Incoherent	105	100% coverage 75-86 km and 110-111.5 km and 112.5-131 km.		131.0
LORAD	110	ZDC 60%, 75-118 km; 100% coverage, 120->135 km		
RAYMODE X Coherent	110	100% coverage 0-89.5 km. ZDC 30%, 90-106.5 km; 100% coverage, 107.5-131 5 km		131.5
RAYMODE X Incoherent	110	100% coverage to 87 km, 92-96 km; 108-132 km		132.0

2. ZDC = Zonal Detection Coverage in percentage of the indicated range interval over which detection is possible.

3. Convergence Zone is multi-lobed to 94 dB for RAYMODE X coherent, double-lobed to 90 dB for RAYMODE X incoherent.

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(C) Table IIIE-5. Detection Range in km as a Function of Figure of Merit (FOM) in dB for LORAD Run 8S Data and RAYMODE X Model Results. (ASCIC: Source Depth = 15 m, Receiver Depth = 30 m, Frequency = 530 Hz). Bottom Loss: MGS Type 7.

Data Set	FOM	3rd CZ[1] Start	3rd CZ[1] End
LORAD 8S	85	184.5	185.5
RAYMODE X Coherent	85	181.5	186.5
RAYMODE X Incoherent	85	181.5	183.0
LORAD 8S	90	184.0	189.0
RAYMODE X Coherent	90	181.0	187.5
RAYMODE X Incoherent	90	180.5	186.5
LORAN 8S	95	182.0	191.0
RAYMODE X Coherent	95	181.0	191.0
RAYMODE X Incoherent	95	180.0	189.0
LORAD 8S	100	182.0	192.0
RAYMODE X Coherent	100	180.5	193.0
RAYMODE X Incoherent	100	180.5	192.0
LORAD 8S	105	181.0	193.5
RAYMODE X Coherent	105	180.5	193.5
RAYMODE X Incoherent	105	180.0	193.5
LORAD 8S	110	179.0	194.0
RAYMODE X Coherent	110	180.0	194.0
RAYMODE X Incoherent	110	-----	194.5

1. Convergence Zone is multi-lobed to 99 dB for RAYMODE X coherent, double-lobed to 97 dB for RAYMODE X Incoherent.

(C) Table IIIE-6. Detection Range in km as a Function of Figure of Merit (FOM) in dB for LORAD Run 10S Data and RAYMODE X Model Results. Case ID: (Source Depth = 15 m, Receiver Depth = 30 m, Frequency = 530 Hz.). Bottom Loss: MGS Type 7.

Data Set	FOM	4th CZ[1] Start	4th CZ[1] End
LORAD 10S	90	240.5	251.5
RAYMODE X Coherent	90	242.0	249.5
RAYMODE X Incoherent	90	242.0	245.0
LORAD 10S	95	238.5	252.5
RAYMODE X Coherent	95	241.5	252.0
RAYMODE X Incoherent	95	241.5	253.0
LORAD 10S	100	238.0	253.5
RAYMODE X Coherent	100	241.5	253.0
RAYMODE X Incoherent	100	241.5	253.0
LORAD 10S	105	237.5	254.0
RAYMODE X Coherent	105	241.5	255.0
RAYMODE X Incoherent	105	241.0	255.0

1. Convergence Zone is multi-lobed to 99 dB for RAYMODE X coherent, double-lobed to 98 dB for RAYMODE X Incoherent.

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(C) Table IIIE-7. Detection Range in km as a Function of Figure of Merit (FOM) in dB for LORAD Run 12S Data and RAYMODE X Model Results. Case IE: (Source Depth = 15 m, Receiver Depth = 30 m, Frequency = 530 Hz). Bottom Loss: MGS Type 7.

Data Set	FOM	5th CZ[1] Start	5th CZ[1] End
LORAD 12S	90	307.0	310.5
RAYMODE X Coherent	90	303.0	310.0
RAYMODE X Incoherent	90	304.0	304.0
LORAD 12S	95	305.5	314.5
RAYMODE X Coherent	95	303.0	312.5
RAYMODE X Incoherent	95	303.0	310.0
LORAD 12S	100	304.5	316.0
RAYMODE X Coherent	100	302.0	315.5
RAYMODE X Incoherent	100	302.5	315.5
LORAD 12S	105	302.0	317.0
RAYMODE X Coherent	105	301.0	316.0
RAYMODE X Incoherent	105	302.0	316.5

1. Convergence Zone is multi-lobed to 101 dB for RAYMODE X coherent, double-lobed to 103 dB for RAYMODE X Incoherent.

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(C) Table IIIE-8. Detection Range in km as a Function of Figure of Merit (FOM) in dB for LORAD Run 14S Data and RAYMODE X Model Results. Case IF: (Source Depth = 15 m, Receiver Depth = 30 m, Frequency = 530 Hz). Bottom Loss: MGS Type 7.

Data Set	FOM	6th CZ[1] Start	6th CZ[1] End
LORAD 14S	95	364.0	373.0
RAYMODE X Coherent	95	363.5	373.0
RAYMODE X Incoherent	95	364.0	366.0
LORAD 14S	100	363.5	377.5
RAYMODE X Coherent	100	363.0	376.0
RAYMODE X Incoherent	100	363.5	374.0
LORAD 14S	105	361.0	382.5
RAYMODE X Coherent	105	363.0	380.0
RAYMODE X Incoherent	105	363.0	379.0
LORAD 14S	110	360.5	385.0
RAYMODE X Coherent	110	360.5	381.0
RAYMODE X Incoherent	110	361.0	380.5

1. Convergence Zone is double-lobed to 105 dB for RAYMODE X coherent.

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(C) Table IIIE-9. Detection Range in km as a Function of Figure of Merit (FOM) in dB for LORAD Run 16S Data and RAYMODE X Model Results. Case IG: (Source Depth = 15 m, Receiver Depth = 30 m, Frequency = 530 Hz). Bottom Loss: MGS Type 7.

Data Set	FOM	7th CZ Start	7th CZ End
LORAD 16S	100	423.0	
RAYMODE X Coherent	100	424.0	435.5
RAYMODE X Incoherent	100	424.0	433.5
LORAD 16S	105	420.0	
RAYMODE X Coherent	105	423.5	438.0
RAYMODE X Incoherent	105	424.0	438.0
LORAD 16S	110	418.5	
RAYMODE X Coherent	110	423.5	> 440.0
RAYMODE X Incoherent	110	423.0	> 440.0

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(C) Table IIIE-10. Detection Range in km as a Function of Figure of Merit (FOM) in dB for LORAD RUN 3D Data (4.5-69.5 km) and RAYMODE X Coherent and Incoherent Model Results. Case IIA: (Source Depth = 15 m, Receiver Depth = 305m, Frequency = 530 Hz). Bottom Loss: MGS Type 7.

Data Set	FOM	RC[1]	First Bottom Bounce Region	1st CZ[3] Start	1st CZ[3] End
LORAD 3D	85		ZDC 10%, 8.0-31.5 km; ZDC 60%, 2.5-8.0 km	59.0	65.0
RAYMODE X Coherent	85	4.5		57.5	63.0
RAYMODE X Incoherent	85	4.5		58.0	64.0
LORAD 3D	90		ZDC 90%, 2.5-8.0 km; ZDC 60%, 8-15 km; ZDC 40%, 15-32 km, ZDC 40%, 32-40 km	57.5	65.5
RAYMODE X Coherent	90	6.5	Coverage at 8.0, and 10.5 km	57.0	65.0
RAYMODE X Incoherent	90	6.0		58.0	65.0
LORAD 3D	95		ZDC 90%, 2.5-30.0 km; ZDC 80%, 30-40 km; ZDC 20%, 40-50 km	55.5	66.5
RAYMODE X Coherent	95	6.5	ZDC 50%, 7.5-11.5 km 100% coverage 16.5-17 km	57.0	66.0
RAYMODE X Incoherent	95	11.0		57.0	65.5
LORAD 3D	100	32.0	ZDC 90%, 32-41 km, ZDC 50%, 41-50 km; ZDC 20%, 50-58.5 km	55.0	67.0
RAYMODE X Coherent	100	13.0	ZDC 25%, 15-40.5 km; 100% coverage, 41-67 km.		67.0
RAYMODE X Incoherent	100	24.0		56.0	67.0
LORAD 3D	105	41.5	ZDC 95%, 41.5-50 km; ZDC 50%, 50-58 km		
RAYMODE X Coherent	105	13.5	100% coverage 44-44.5 km, 38-39.5 km; ZDC 60%, 14-43 km	55.0	67.0
RAYMODE X Incoherent	105	42.0		54.0	67.5
LORAD 3D	110	52.0	ZDC 50%, 52-57 km		
RAYMODE X Coherent	110	13.5	ZDC 75%, 14-49.5 km; 100% coverage, 50-69.5 km		69.5
RAYMODE X Incoherent	110	70.0			

1 R_c = Range to which coverage is continuous.

2 ZDC = Zonal Detection Coverage in percentage of the indicated interval over which detection is possible.

3 Convergence Zone is double-lobed to 106 dB for RAYMODE X coherent, to 93 dB for RAYMODE X Incoherent.

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(C) Table IIIE-11. Detection Range in km as a Function of Figure of Merit (FOM) in dB for LORAD Run 6D (71-134 km) and RAYMODE X Coherent and Incoherent Model Results. Case IIB: (Source Depth = 15 m, Receiver Depth = 305 m, Frequency = 530 Hz). Bottom Loss: MGS Type 7.

Data Set	FOM	Second Bottom Bounce Region	2nd CZ[3] Start	2nd CZ[3] End
LORAD 6D	90		120.5	127.5
RAYMODE X Coherent	90		118.5	125.0
RAYMODE X Incoherent	90		119.0	125.0
LORAD 6D	95		118.0	128.0
RAYMODE X Coherent	95		118.5	128.0
RAYMODE X Incoherent	95		118.5	127.0
LORAD 6D	100		117.0	129.0
RAYMODE X Coherent	100		118.0	129.0
RAYMODE X Incoherent	100		118.0	128.5
LORAD 6D	105	ZDC[2] 10%, 71-97.5 km	115.5	131.0
RAYMODE X Coherent	105		118.0	132.0
RAYMODE X Incoherent	105		118.0	130.5
LORAD 6D	110	ZDC 90%, 71-78 km; ZDC 50%, 78-113 km	115.0	132.0
RAYMODE X Coherent	110		118.0	133.0
RAYMODE X Incoherent	110		118.0	133.0
LORAD 6D	115	ZDC 90%, 71-106 km; ZDC 70%, 106-115 km	-----	-----
RAYMODE X Coherent	115	ZDC 75%, 76.5-86.0 km; ZDC 70%, [illegible]18-116 km	117.0	134.0
RAYMODE X Incoherent	115	100% coverage 79-83 km, 84-87 km	113.0	134.0

2. ZDC = Zonal Detection Coverage in percentage of the indicated range interval over which detection is possible.

3. Convergence Zone is multi-lobed to 102 dB for RAYMODE X coherent, to 98 dB for RAYMODE X Incoherent.

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(C) Table IIIE-12. Detection Range in km as a Function of Figure of Merit (FOM) in dB for LORAD Run 8D Data and RAYMODE X Model Results. Case IIC: (Source Depth = 15 m. Receiver Depth = 305 m, Frequency = 530 Hz). Bottom Loss: MGS Type 7.

Data Set	FOM	3rd CZ[1] Start	3rd CZ[1] End
LORAD 8D	90	182.5	186.0
RAYMODE X Coherent	90	180.0	180.0
RAYMODE X Incoherent	90	-----	------
LORAD 8D	95	180.5	190.5
RAYMODE X Coherent	95	179.0	188.5
RAYMODE X Incoherent	95	179.0	187.0
LORAD 8D	100	177.0	195.5
RAYMODE X Coherent	100	179.0	190.5
RAYMODE X Incoherent	100	179.0	190.0
LORAD 8D	105	175.0	196.0
RAYMODE X Coherent	105	179.0	193.0
RAYMODE X Incoherent	105	179.0	191.0
LORAD 8D	110	173.5	199.0
RAYMODE X Coherent	110	178.5	195.0
RAYMODE X Incoherent	110	178.5	195.0

1. Convergence Zone is double-lobed to 108 dB for RAYMODE X coherent, to 103 dB for RAYMODE X Incoherent.

(C) Table IIIE-13. Detection Range in km as a Function of Figure of Merit (FOM) in dB for LORAD Run 10D Data and RAYMODE X Model Results. Case IID: (Source Depth = 15 m. Receiver Depth = 305 m, Frequency = 530 Hz). Bottom Loss: MGS Type 7.

Data Set	FOM	4th CZ[1] Start	4th CZ[1] End
LORAD 10D	95	240.0	-----
RAYMODE X Coherent	95	240.0	247.5
RAYMODE X Incoherent	95	241.0	245.5
LORAD 10D	100	238.0	-----
RAYMODE X Coherent	100	240.0	253.5
RAYMODE X Incoherent	100	240.0	250.5
LORAD 10D	105	234.0	-----
RAYMODE X Coherent	105	239.5	254.0
RAYMODE X Incoherent	105	240.0	254.0
LORAD 10D	110	232.0	-----
RAYMODE X Coherent	110	239.0	254.0
RAYMODE X Incoherent	110	239.0	254.0

1. Convergence Zone is multi-lobed with losses from 106 to 120 dB for RAYMODE X coherent, to 105 dB for RAYMODE X Incoherent.

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(C) Table IIIE-14. Detection Range in km as a Function of Figure of Merit (FOM) in dB for LORAD Run 12D Data and RAYMODE X Model Results. Case IIE: (Source Depth = 15 m. Receiver Depth = 305 m, Frequency = 530 Hz). Bottom Loss: MGS Type 7.

Data Set	FOM	5th CZ[1] Start	5th CZ[1] End
LORAD 12D	100	299.0	316.5
RAYMODE X Coherent	100	301.0	313.0
RAYMODE X Incoherent	100	301.0	307.0
LORAD 12D	105	293.0	318.0
RAYMODE X Coherent	105	301.0	317.0
RAYMODE X Incoherent	105	301.0	317.0
LORAD 12D	110	290.5	319.5
RAYMODE X Coherent	110	300.5	318.0
RAYMODE X Incoherent	110	300.5	317.5

1. Convergence Zone is multi-lobed with losses from 110 dB to 123 dB for RAYMODE X coherent, to 111 dB for RAYMODE X Incoherent.

(C) Table IIIE-15. Detection Range in km as a Function of Figure of Merit (FOM) in dB for LORAD Run 14D Data and RAYMODE X Model Results. Case IIF: (Source Depth = 15 m. Receiver Depth - 305 m, Frequency = 530 Hz). Bottom Loss: MGS Type 7.

Data Set	FOM	6th CZ[1] Start	6th CZ[1] End
LORAD 14D	105	354.5	379.0
RAYMODE X Coherent	105	362.0	377.0
RAYMODE X Incoherent	105	362.0	375.0
LORAD 14D	110	352.5	380.0
RAYMODE X Coherent	110	361.0	381.0
RAYMODE X Incoherent	110	361.0	380.0

1. Convergence Zone is multi-lobed with losses from 108 dB to 135 dB for RAYMODE X coherent.

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(C) Table IIIE-16. Detection Range in km as a Function of Figure of Merit (FOM) in dB for LORAD Run 16D Data and RAYMODE X Model Results. Case IIG: (Source Depth = 15 m. Receiver Depth = 305 m, Frequency = 530 Hz). Bottom Loss: MGS Type 7.

Data Set	FOM	7th CZ Start	7th CZ End
LORAD 16D	105	417.5	-----
RAYMODE X Coherent	105	423.0	430.0
RAYMODE X Incoherent	105	423.0	430.0
LORAD 16D	110	413.5	-----
RAYMODE X Coherent	110	422.0	-----
RAYMODE X Incoherent	110	422.0	-----

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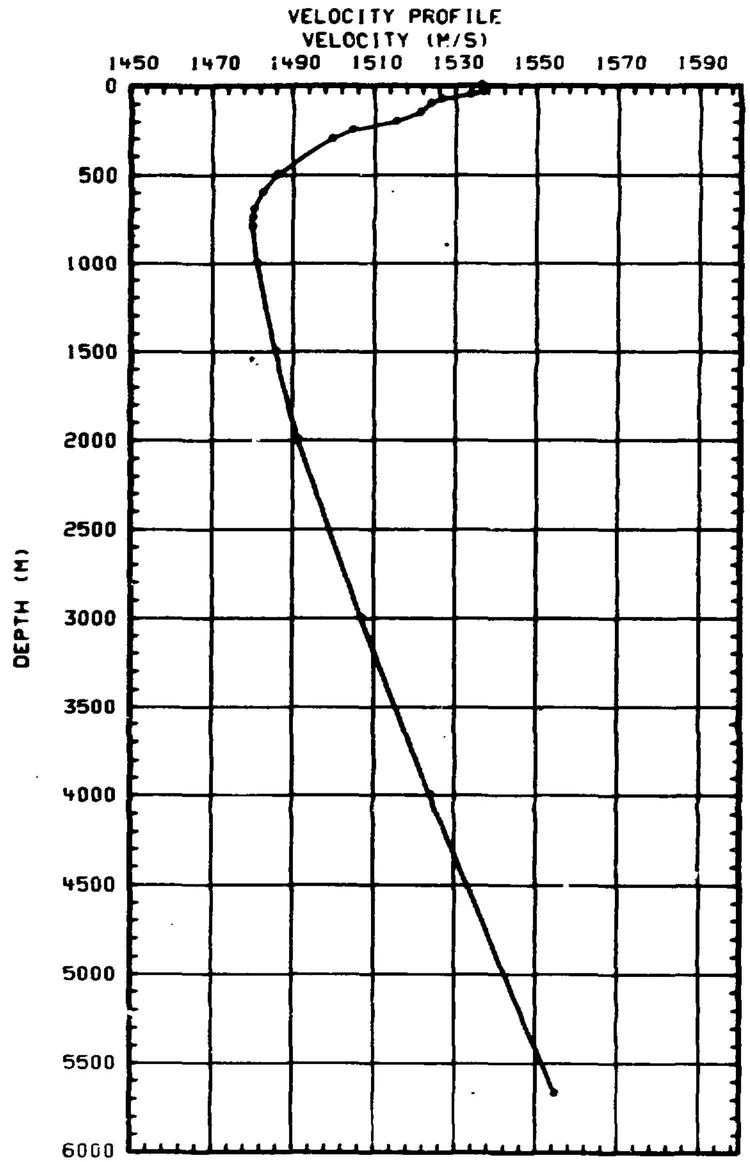
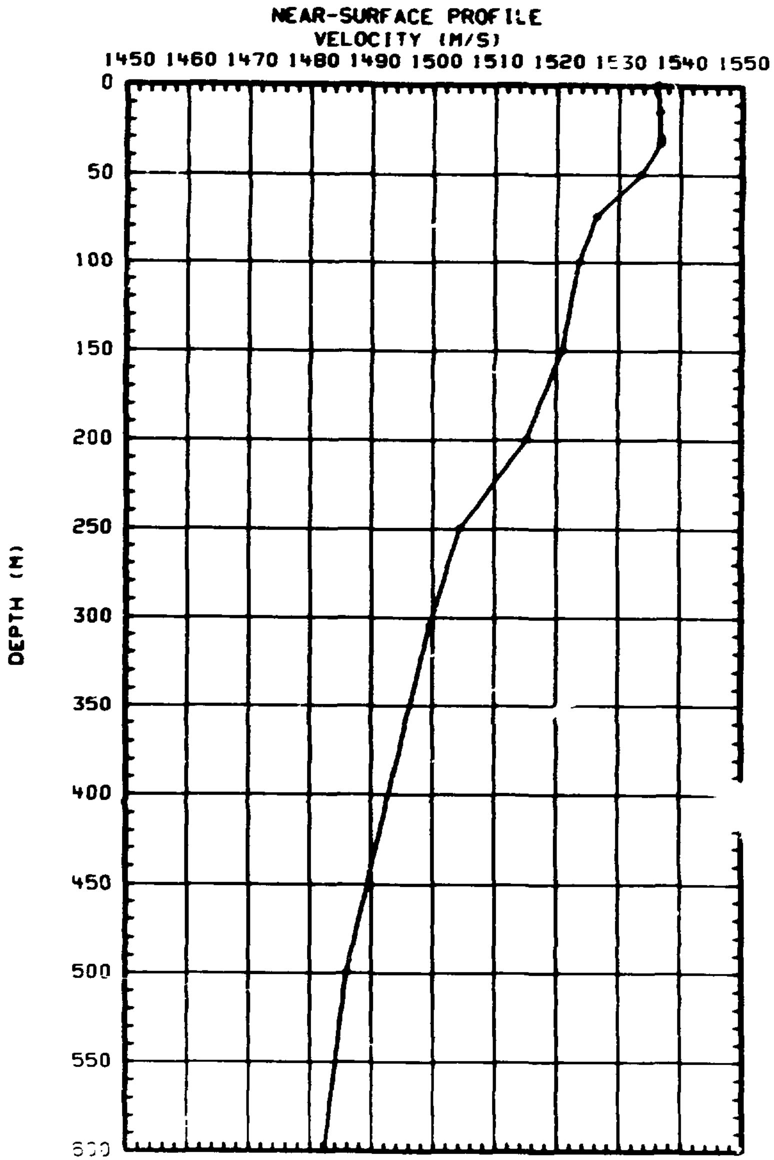


DEPTH	VELOCITY
0.0	1536.20
15.2	1536.50
30.5	1536.80
33.0	1536.80
33.5	1536.70
50.0	1533.60
75.0	1526.30
100.0	1523.60
150.0	1520.80
200.0	1515.10
250.0	1504.30
304.8	1498.42
305.0	1498.40
500.0	1485.90
600.0	1482.30
700.0	1480.10
750.0	1479.90
800.0	1480.00
1000.0	1481.10
1500.0	1485.60
2000.0	1491.30
3000.0	1506.80
4000.0	1523.90
5670.0	1554.70



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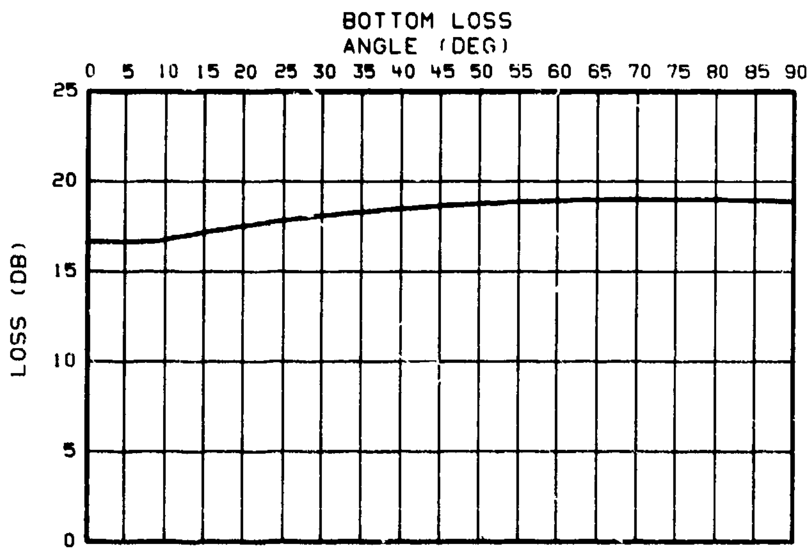
(U) Figure IIIE-1. LORAD Sound Speed Profile



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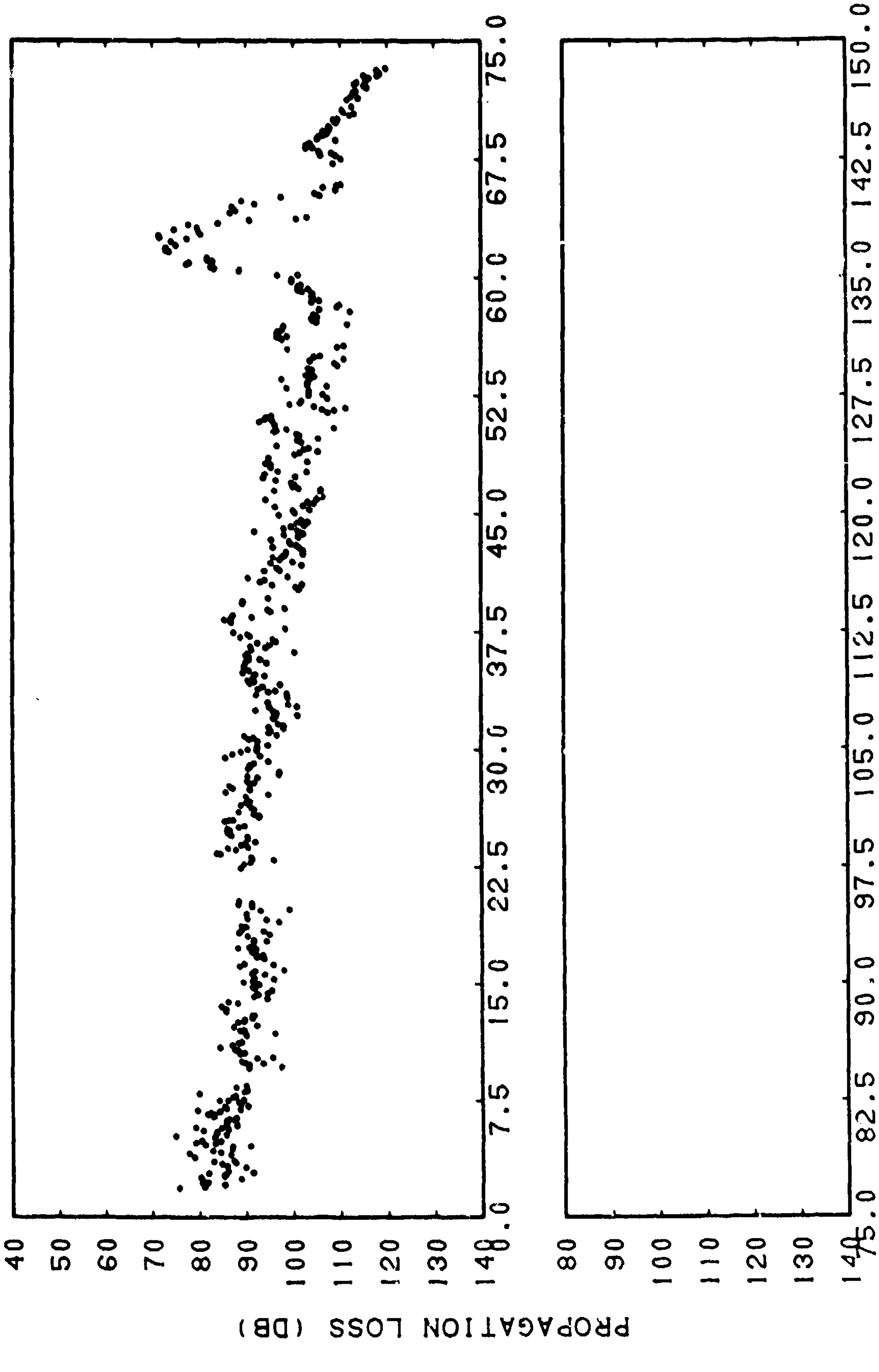
(C) Figure IIIE-2. Bottom Loss in dB Versus Grazing Angle in Degrees. MGS Bottom Type 7. Frequency = 530 Hertz.



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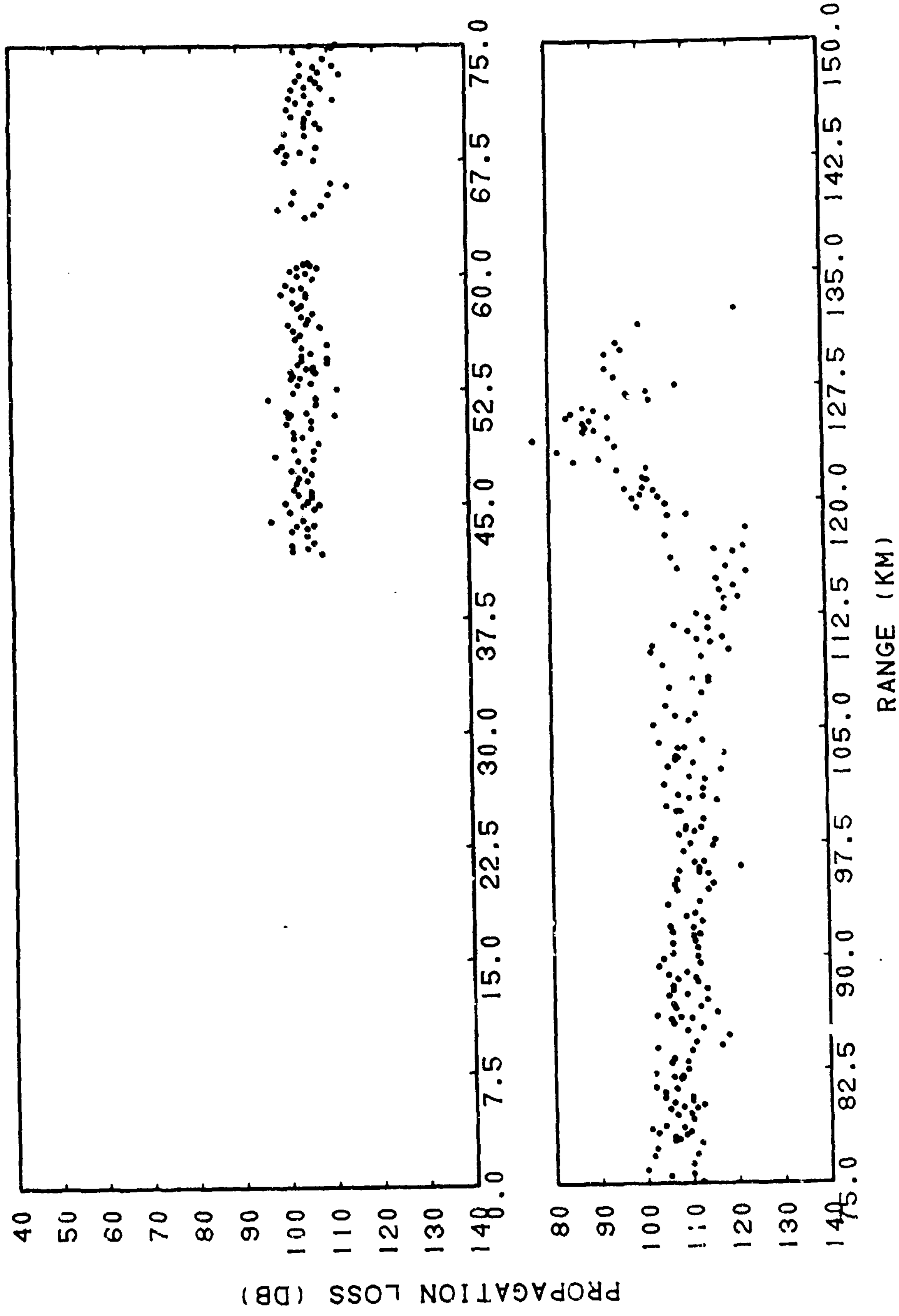
(C) Figure IIIE-3. LORAD Data Run 3S, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 30 Meters



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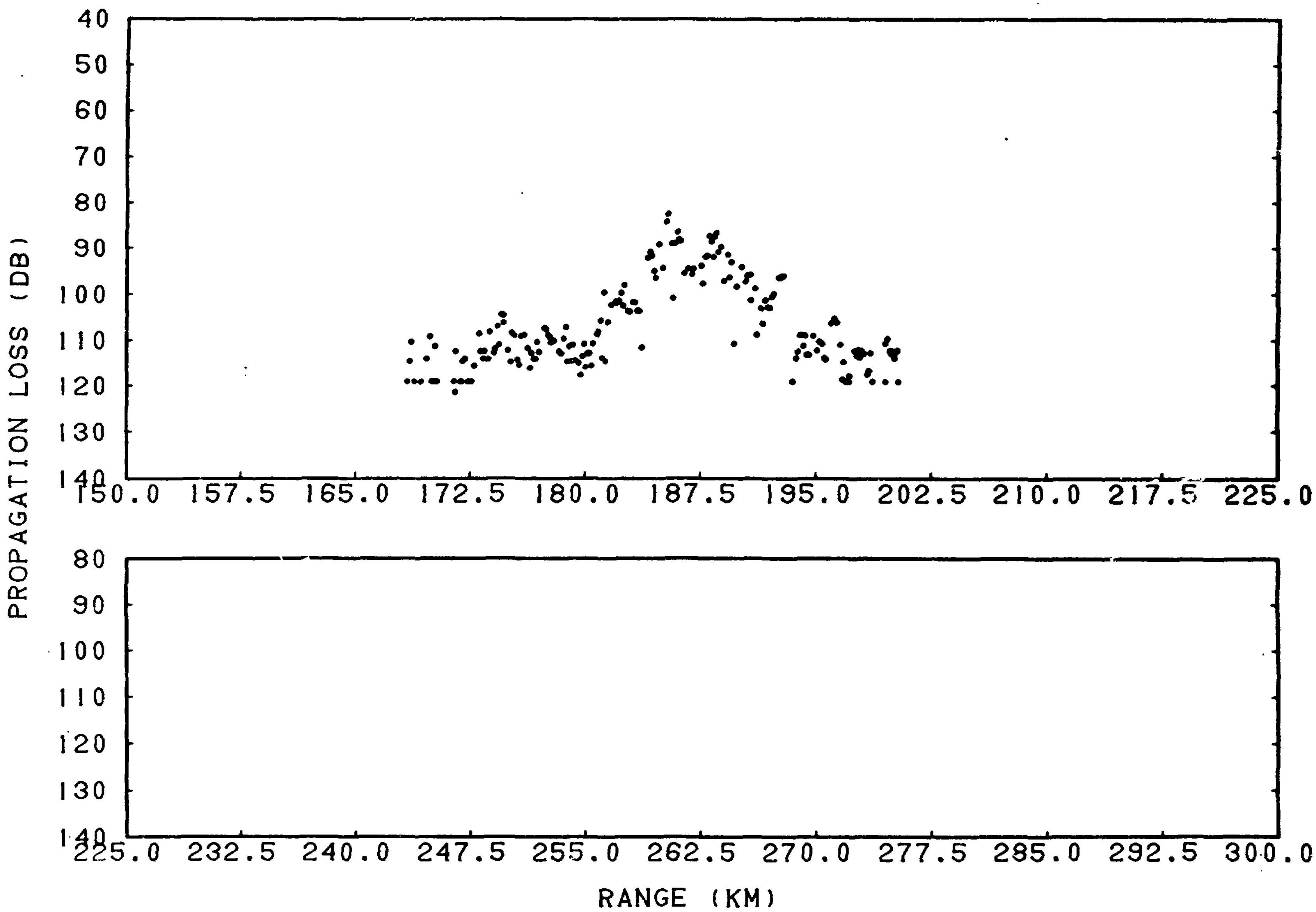
(C) Figure IIIE-4. LORAD Data Run 6S, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 30 Meters



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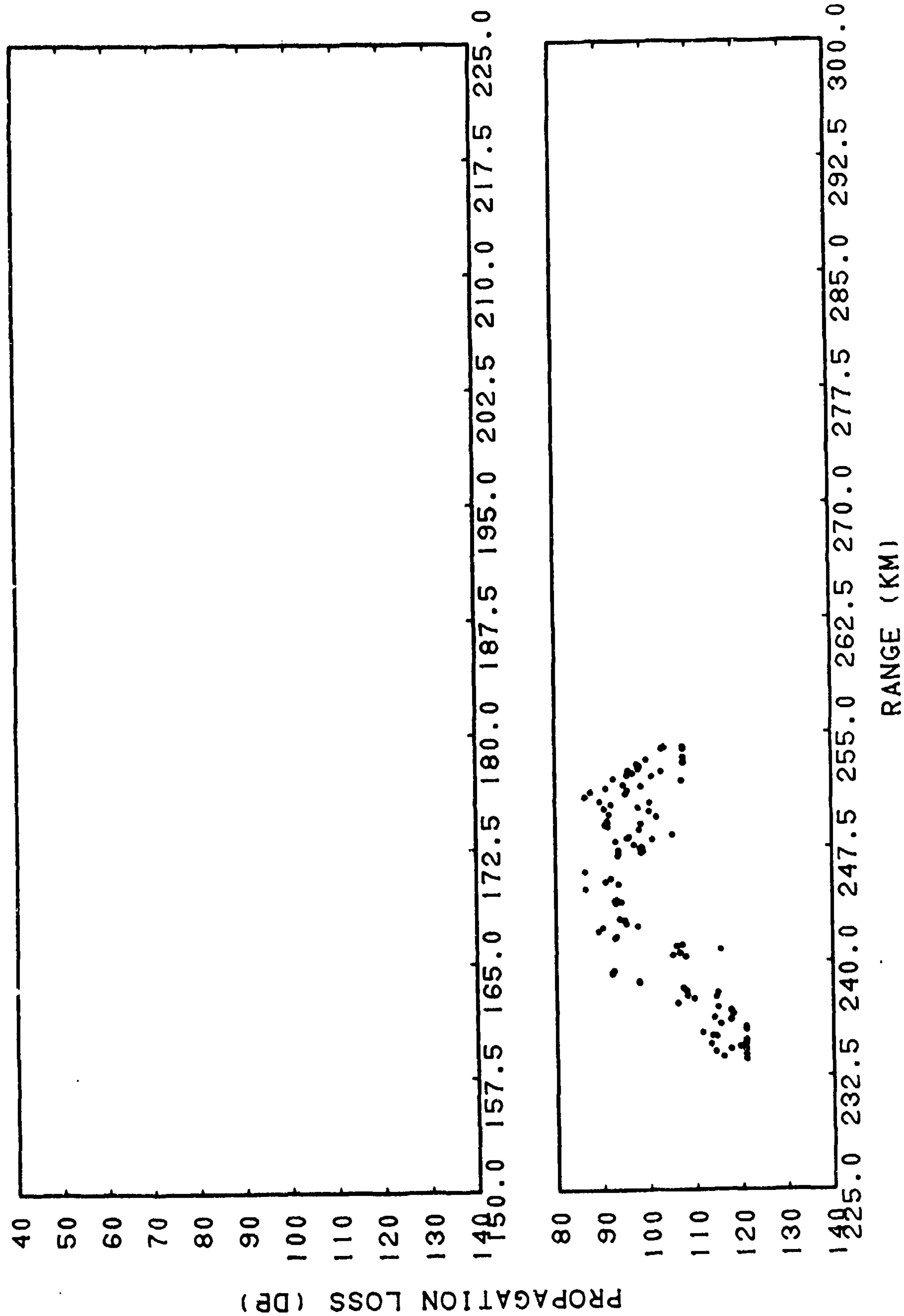
(C) Figure IIIE-5. LORAD Data Run 8S, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 30 Meters



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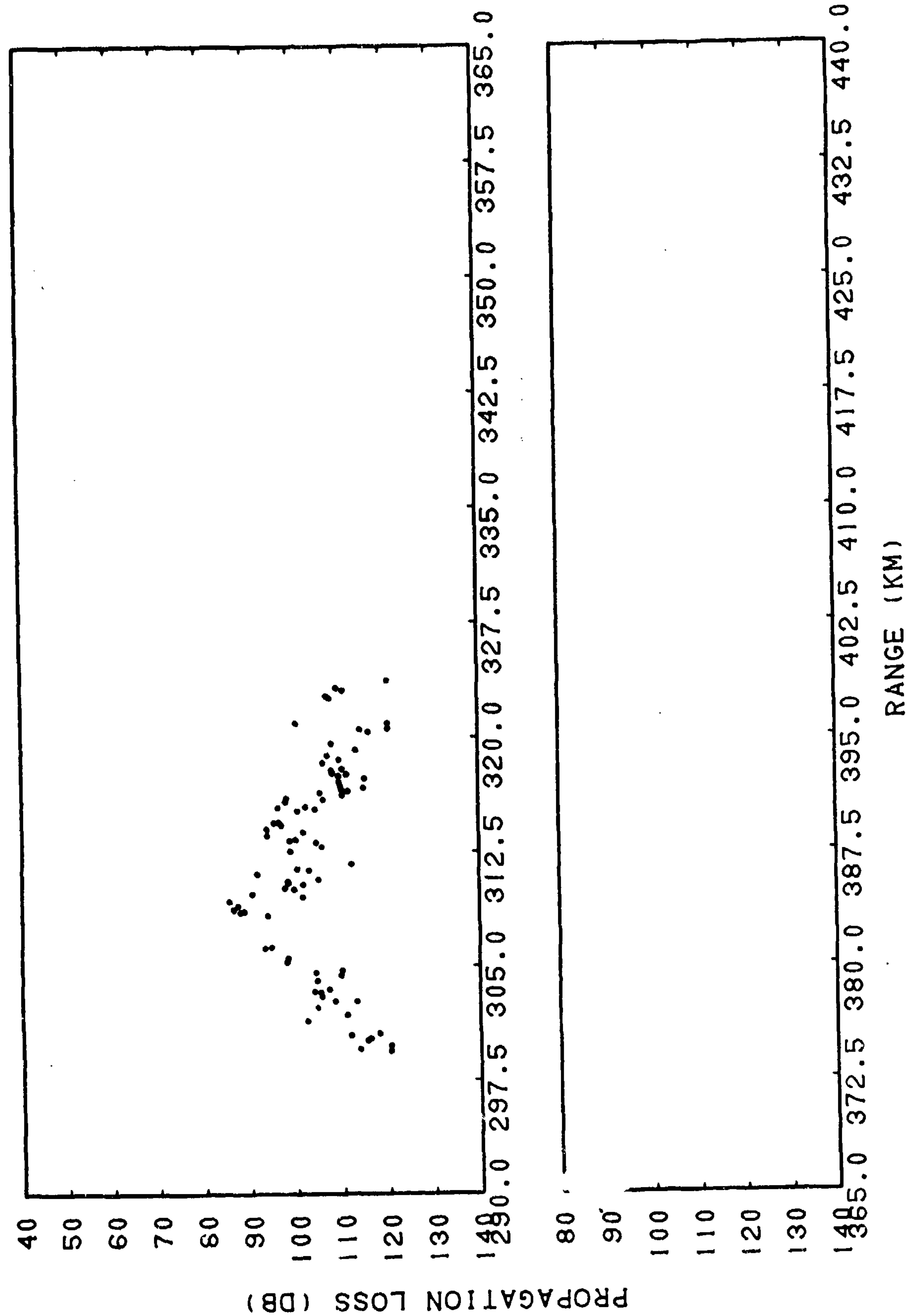
(C) Figure IIIE-6. LORAD Data Run 10S, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 30 Meters



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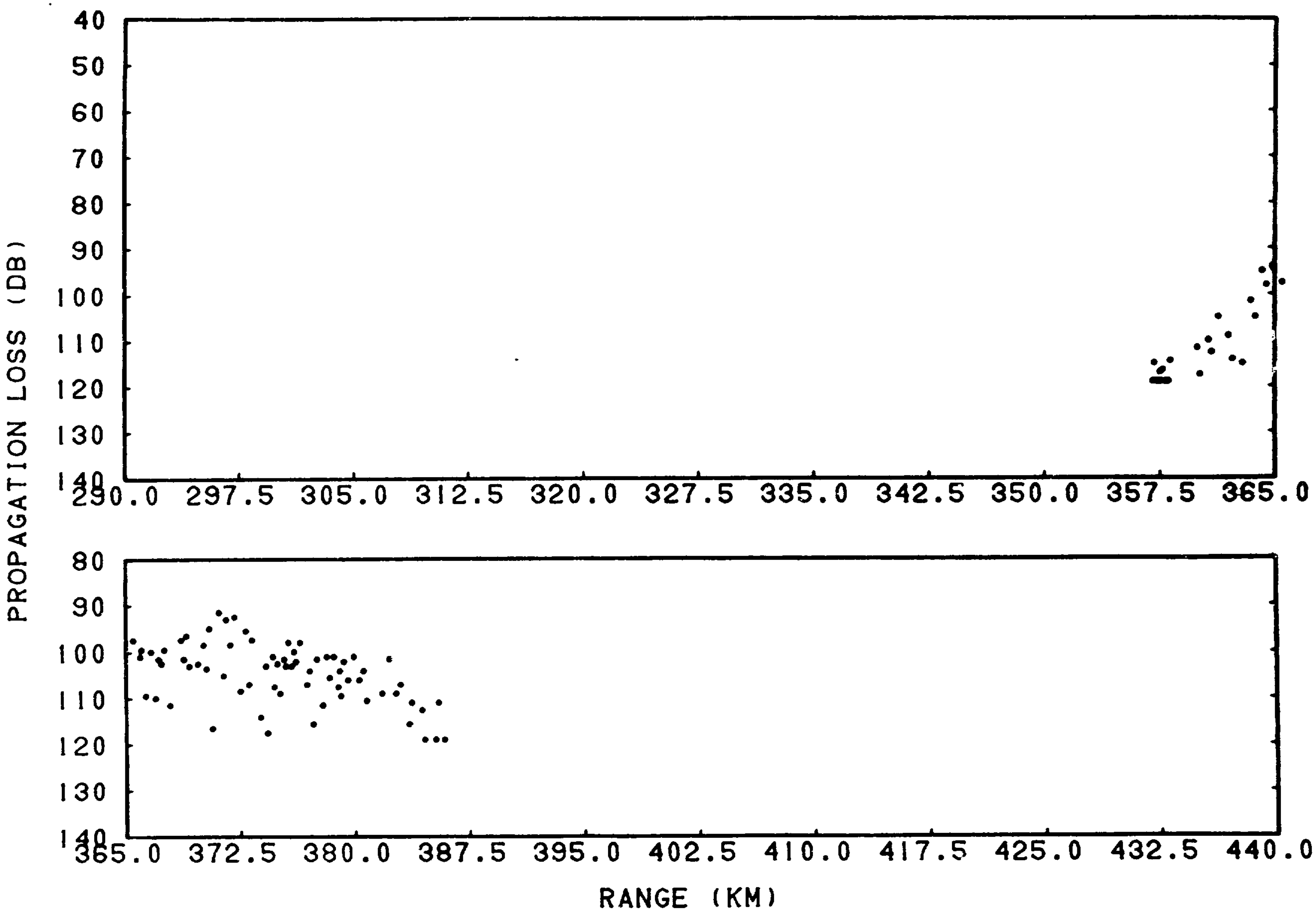
(C) Figure IIIE-7. LORAD Data Run 12S, *Frequency* = 0.53 *Kilohertz*, *Source* Depth = 15 Meters, Receiver Depth = 30 Meters



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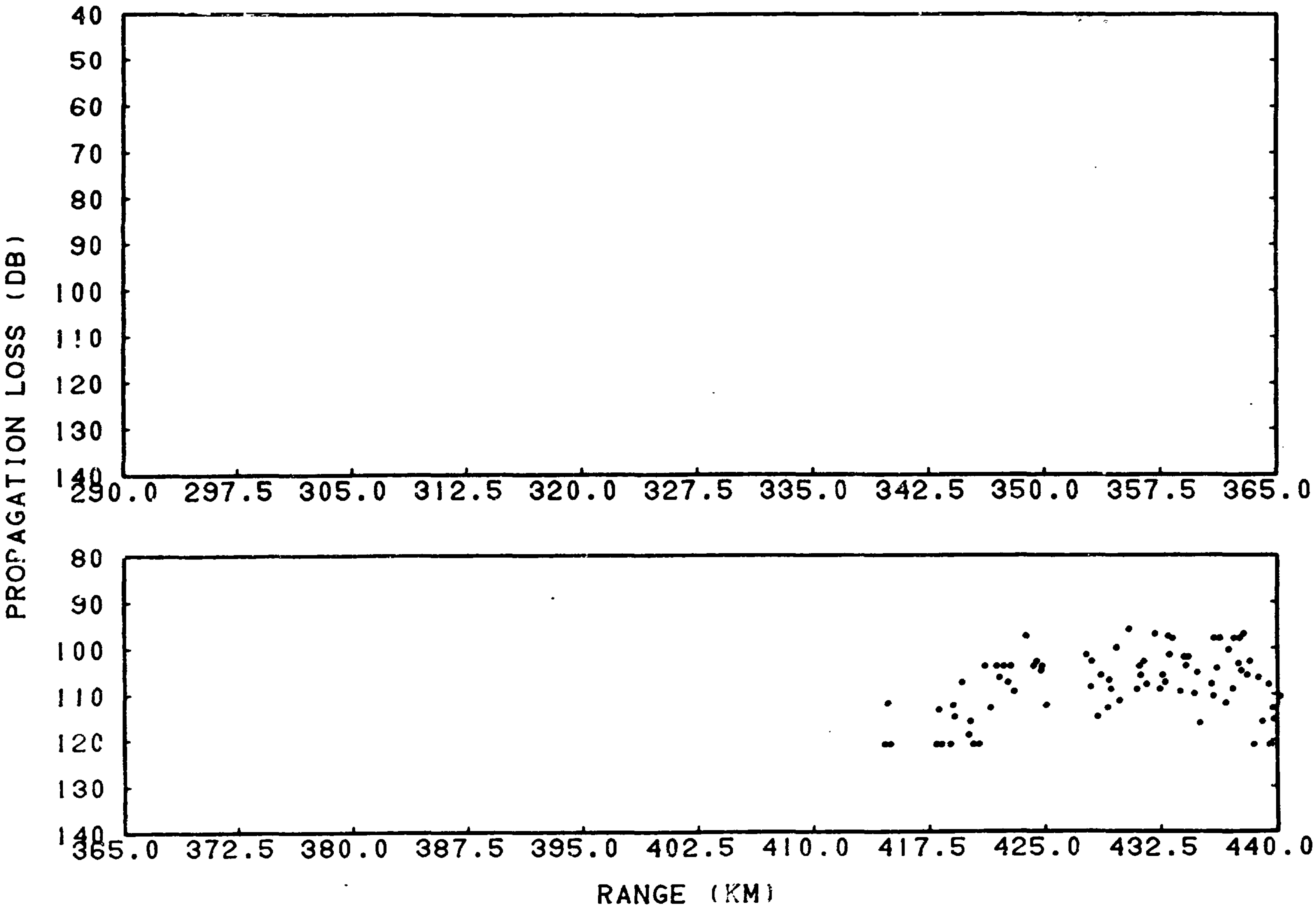
(C) Figure IIIE-8. LORAD Data Run 14S, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 30 Meters



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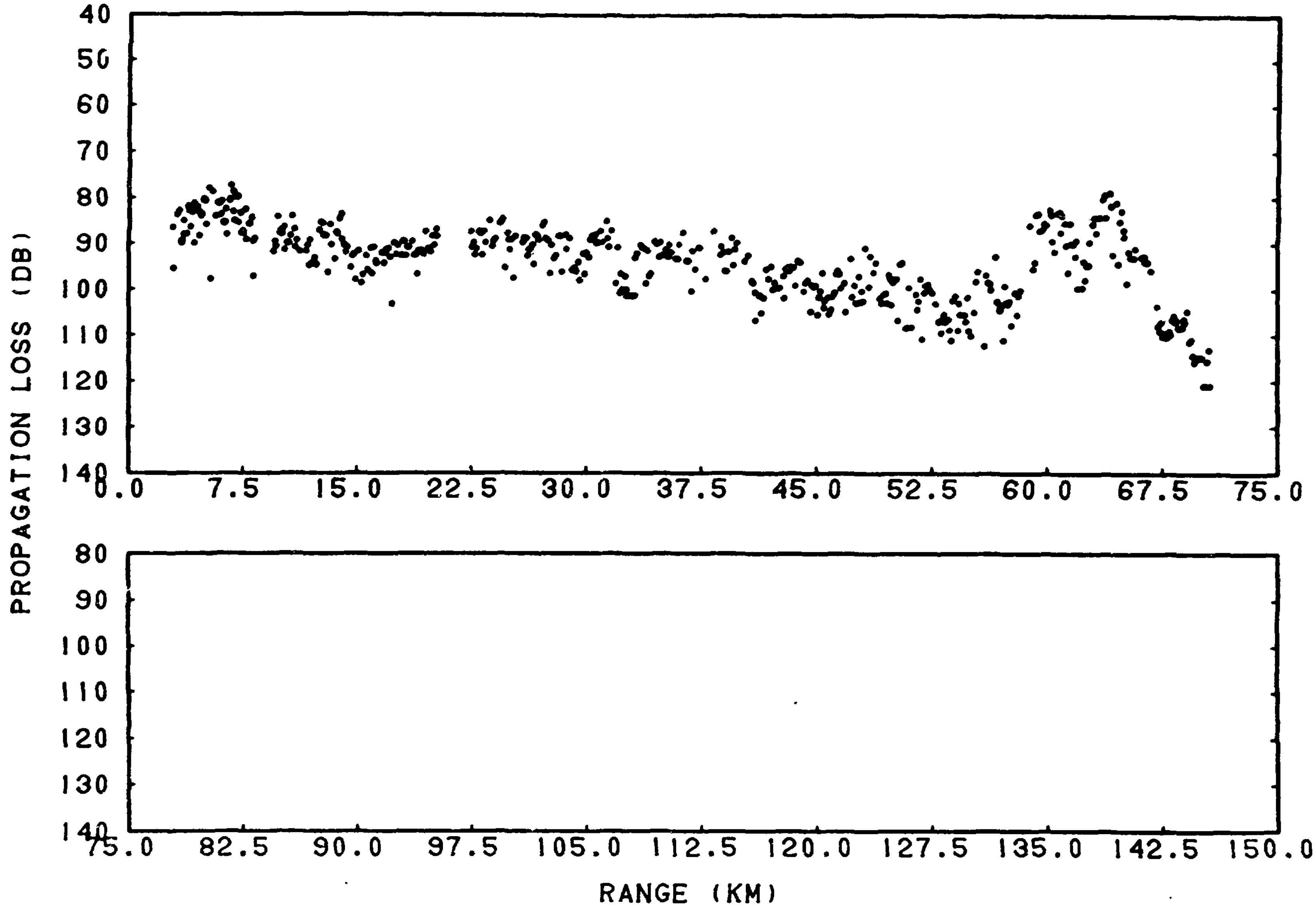
(C) Figure IIIE-9. LORAD Data Run 16S, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 30 Meters



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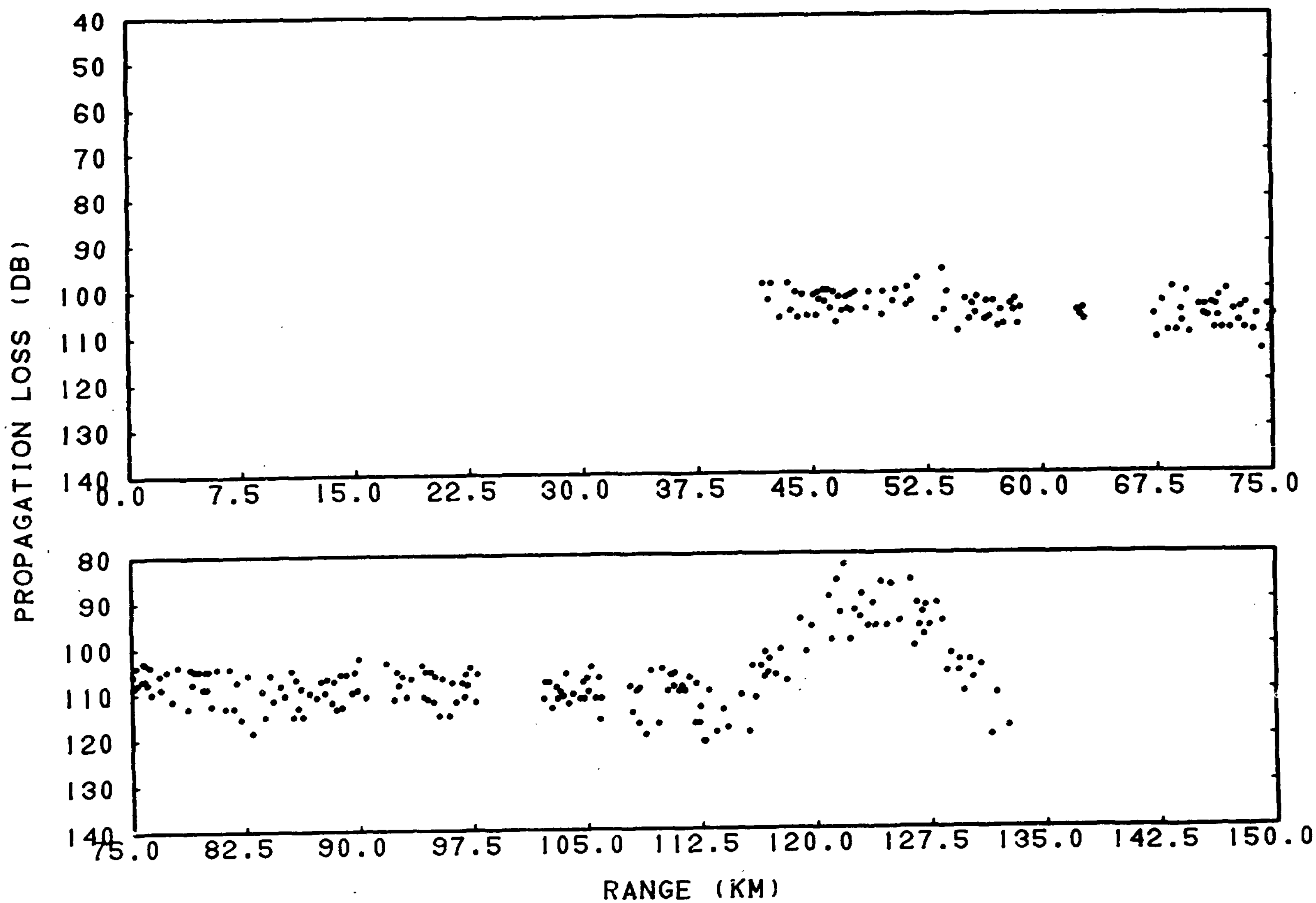
(C) Figure IIIE-10. LORAD Data Run 3D, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 305 Meters



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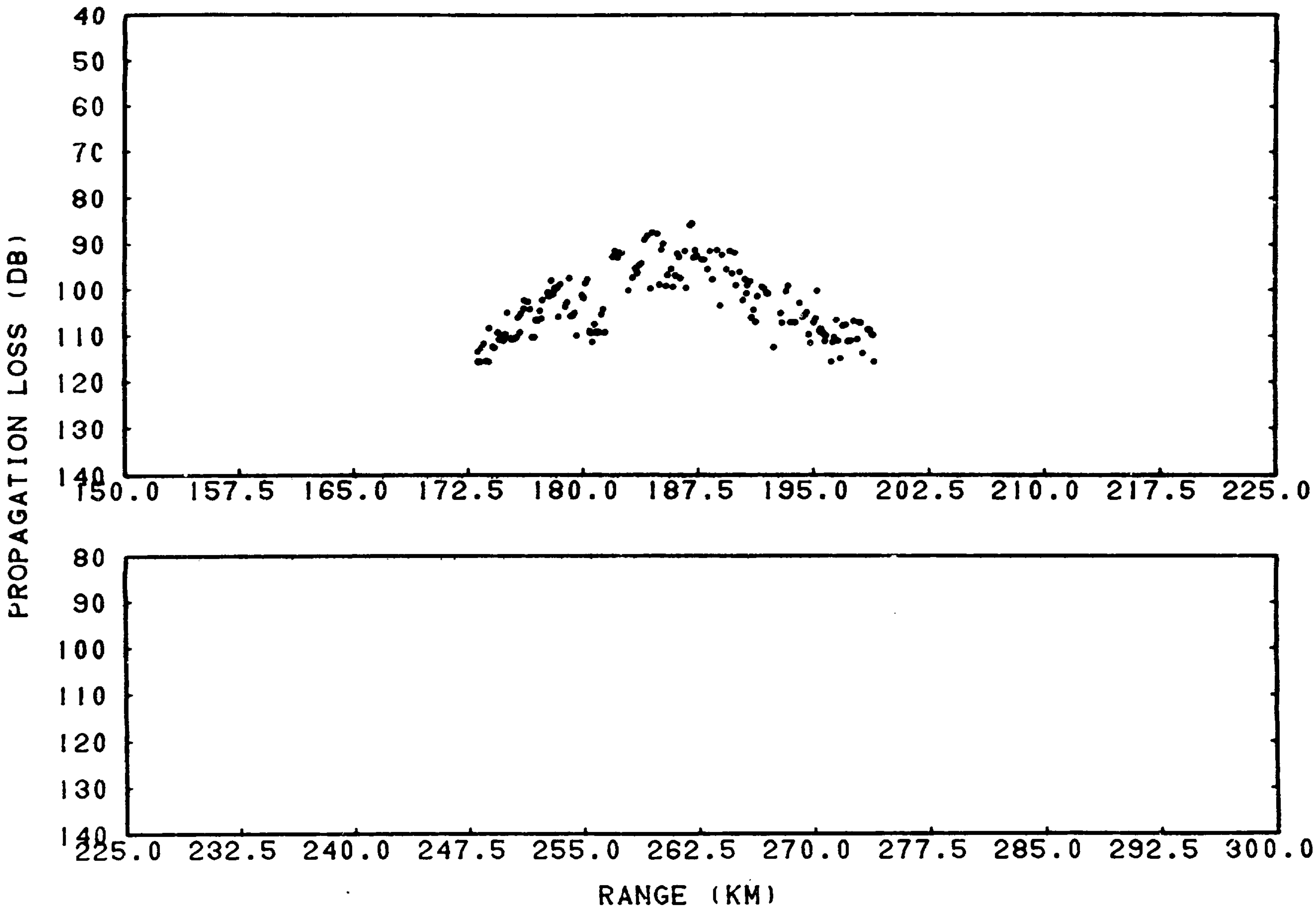
(C) Figure IIIE-11. LORAD Data Run 6D, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 305 Meters



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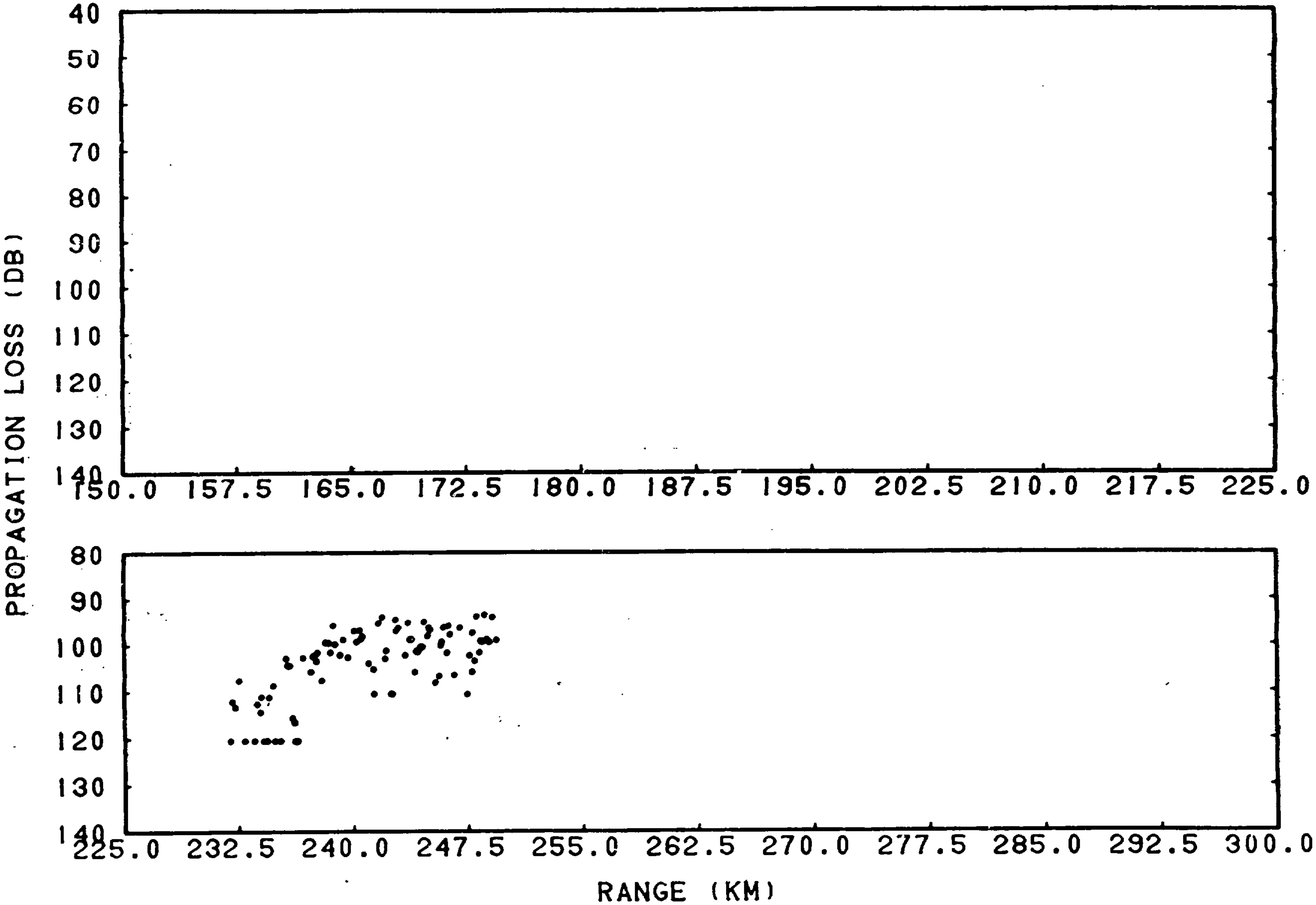
(C) Figure IIIE-12. LORAD Data Run 8D, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 305 Meters



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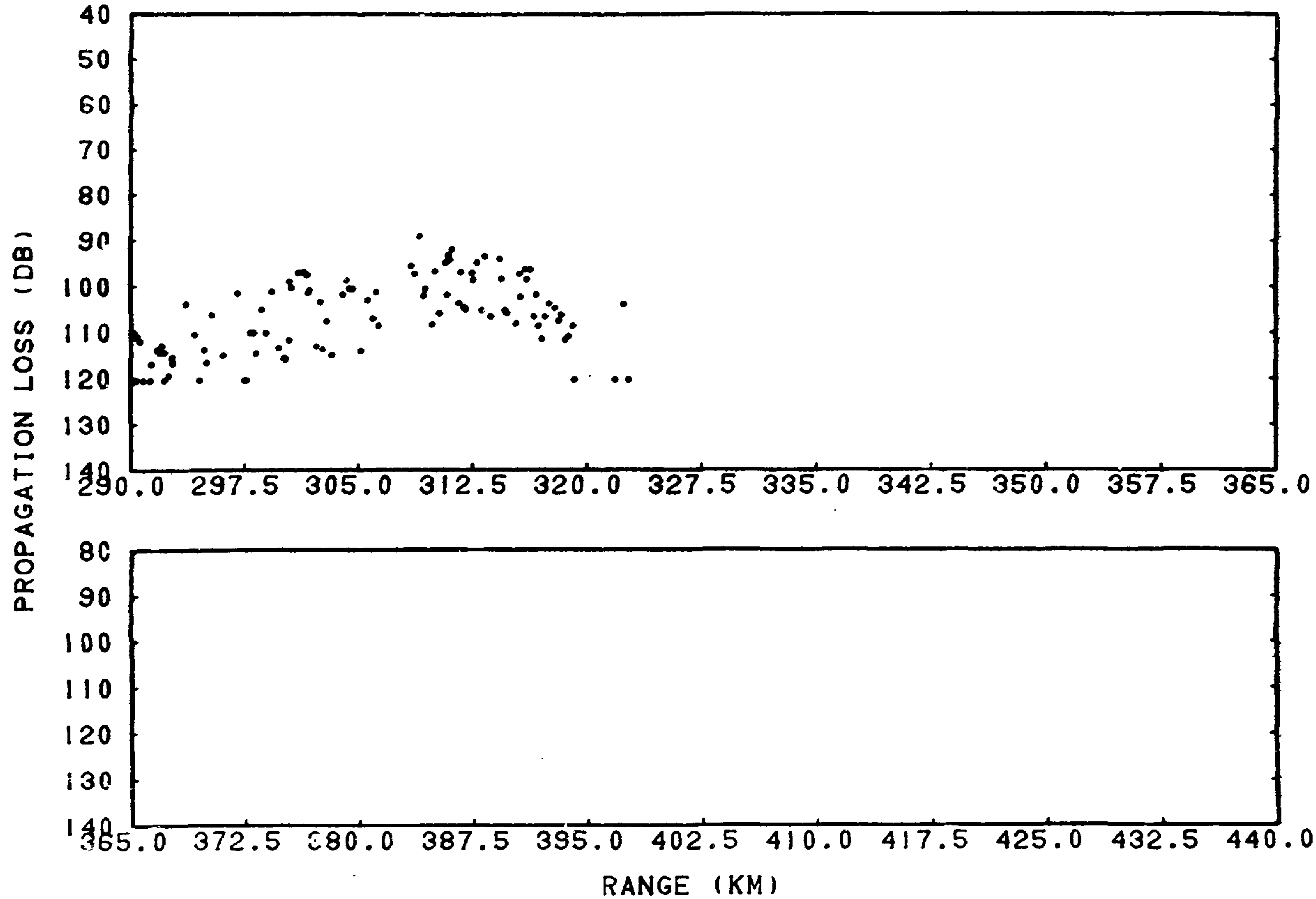
(C) Figure IIIE-13. LORAD Data Run 10D, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 305 Meters



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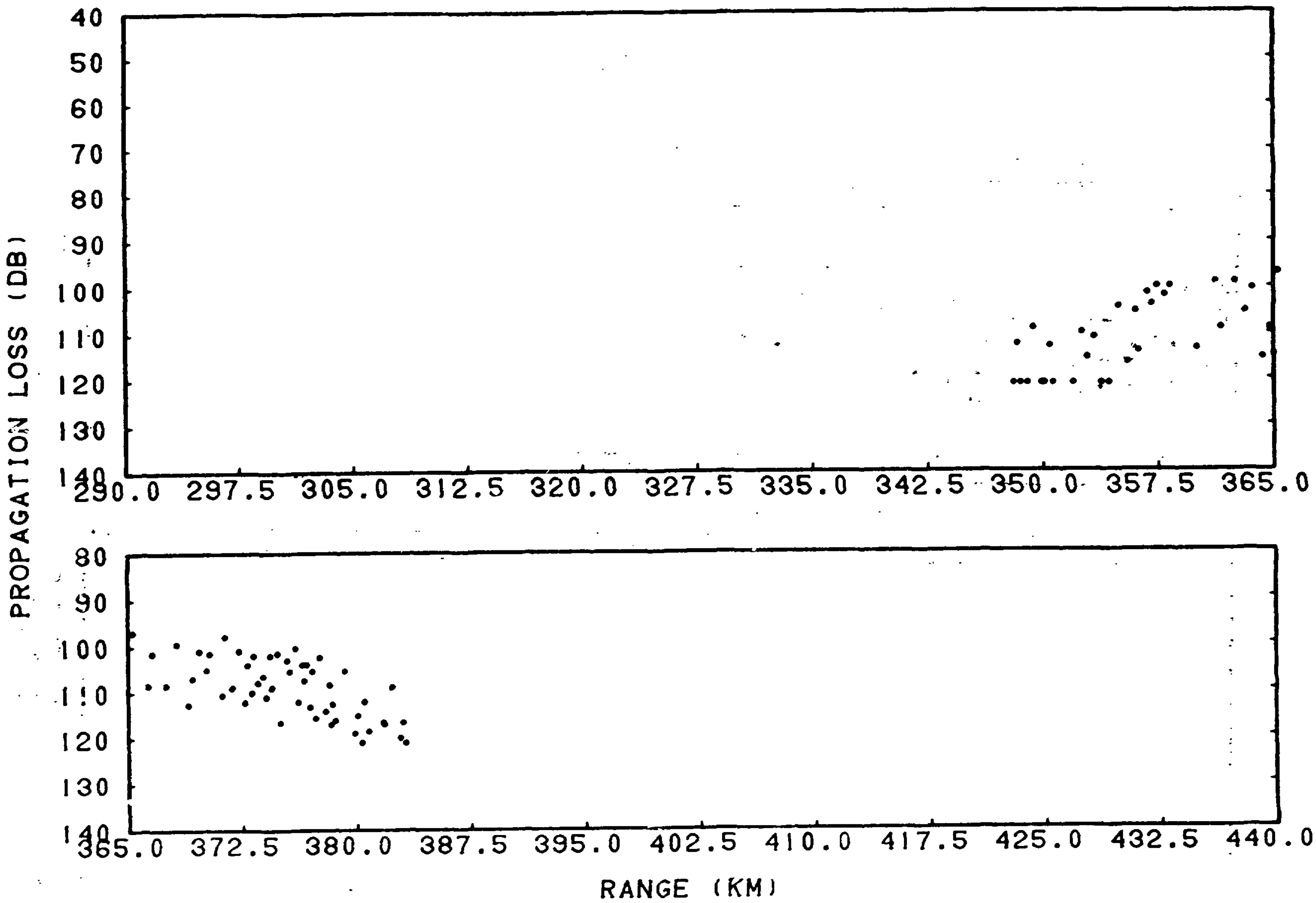
(C) Figure IIIE-14. LORAD Data Run 12D, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 305 Meters



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(C) Figure IIIE-15. LORAD Data Run 14D, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 305 Meters

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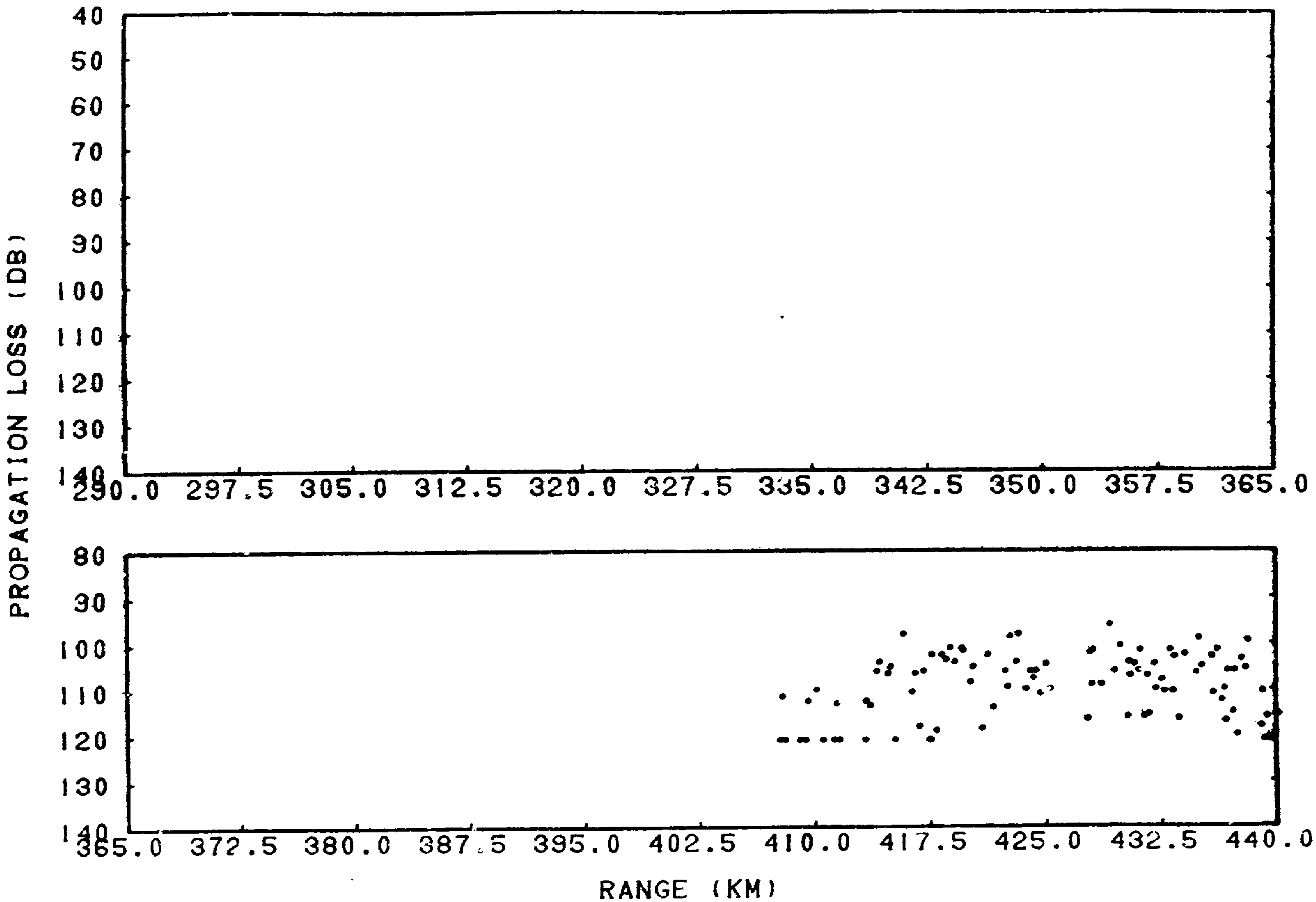

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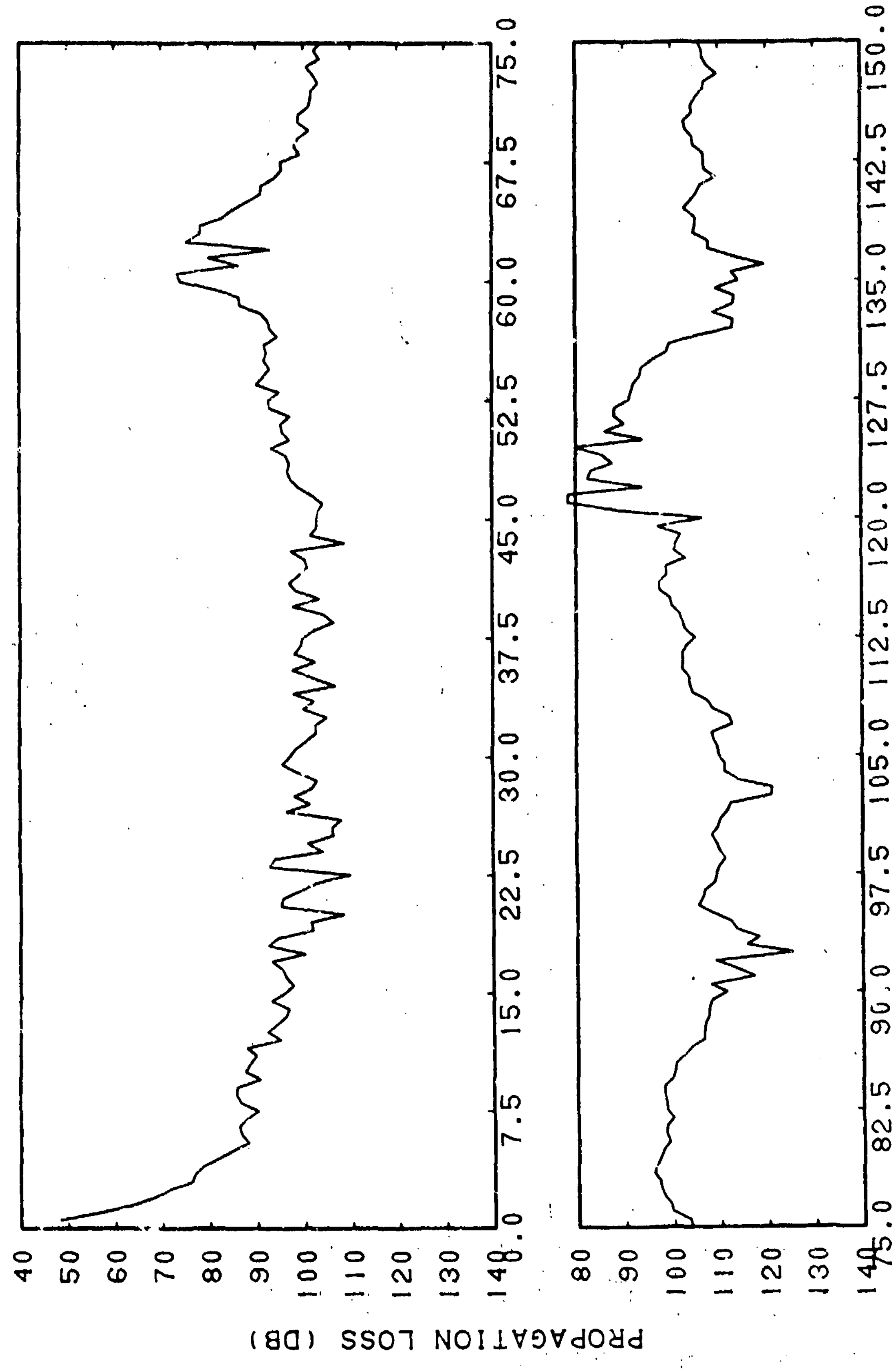
(C) Figure IIIE-16. LORAD Data Run 16D, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 305 Meters



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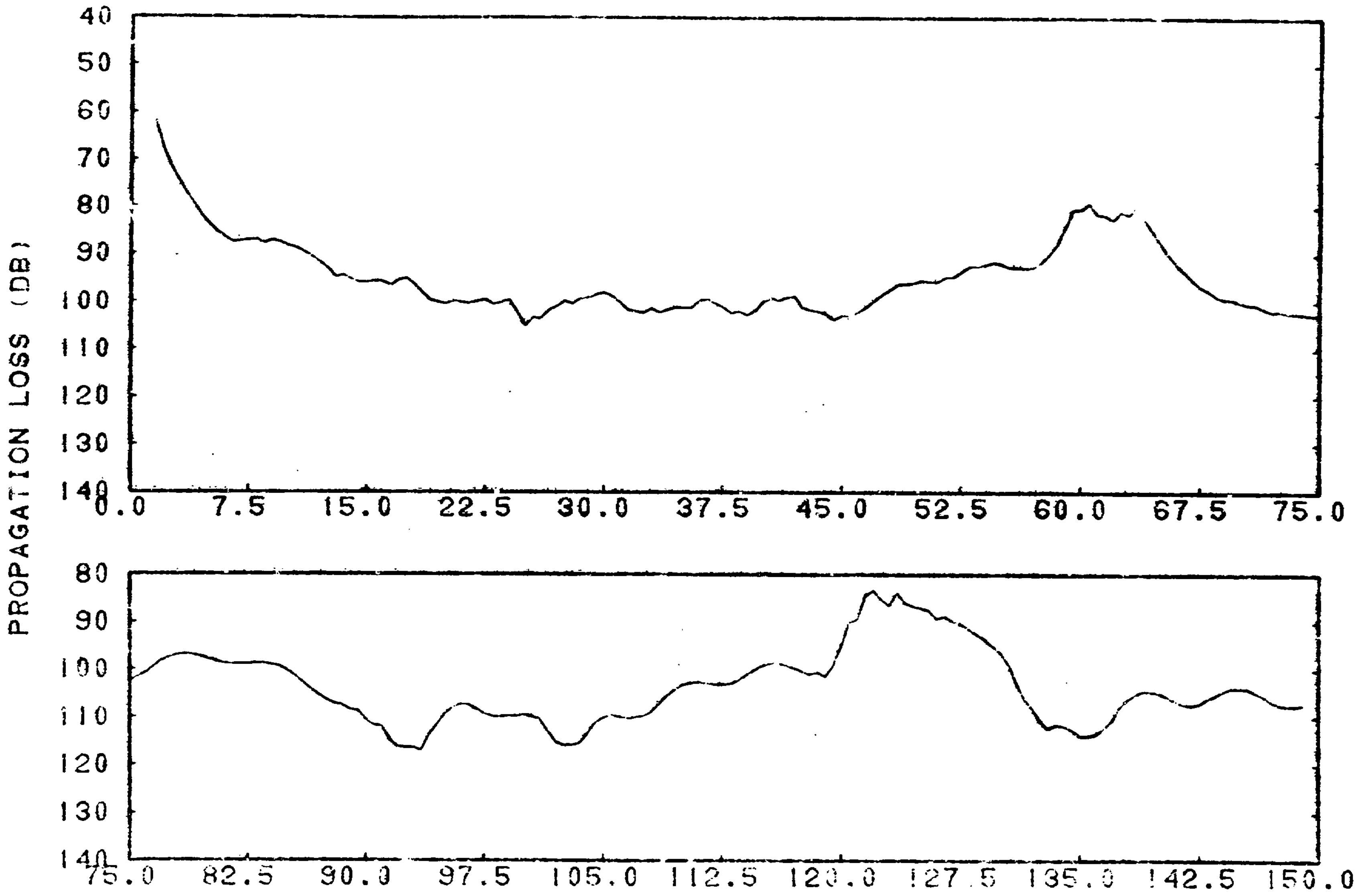
(C) Figure IIIE-17. RAYMODE Coherent, Bottom Loss = MGS 7, Run 3S, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 30 Meters



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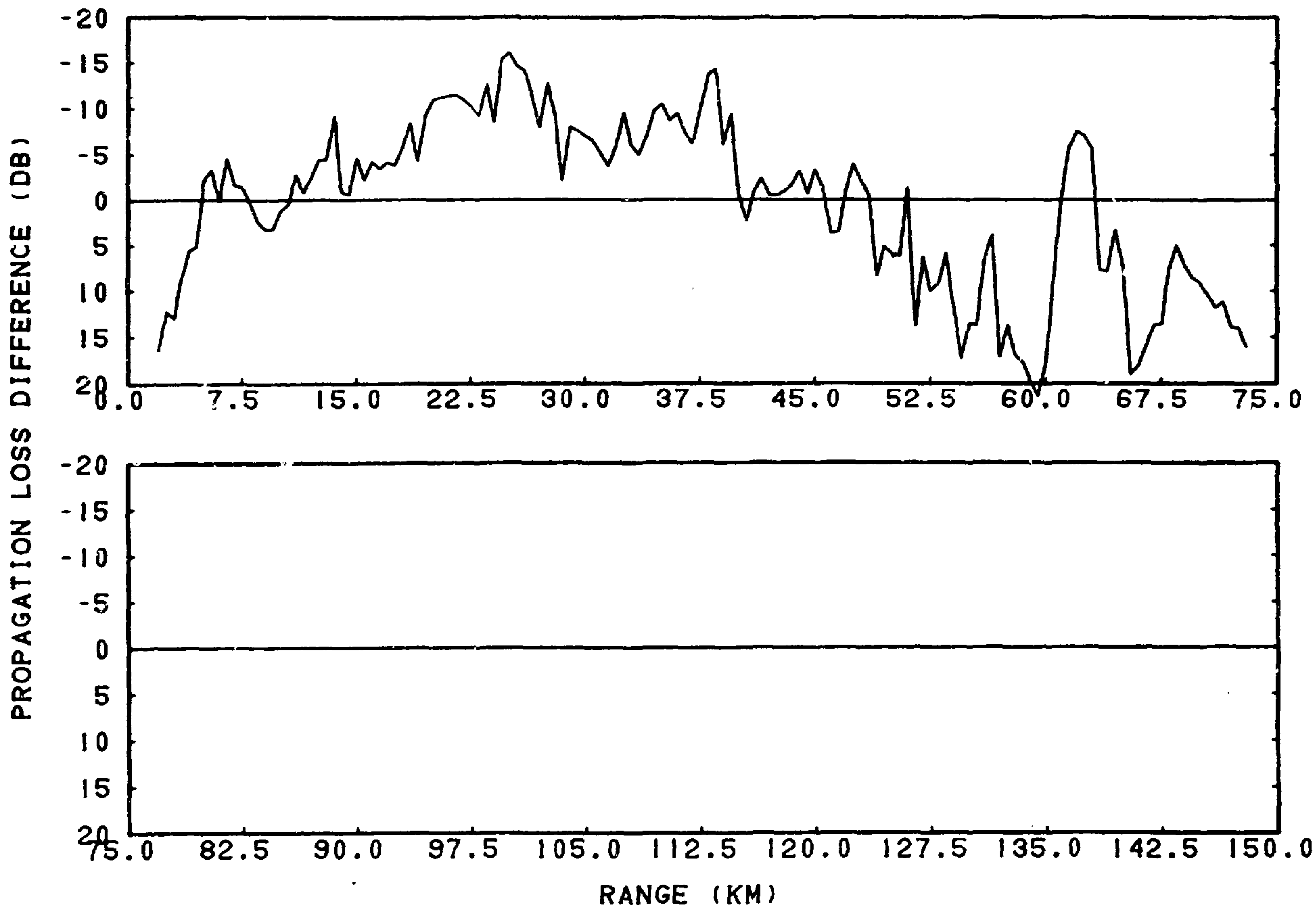
(C) Figure IIIE-18. RAYMODE Coherent, Bottom Loss = MGS 7, Run 3S, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 30 Meters, Sliding Averages of 5 Points (2.00 Kilometers)



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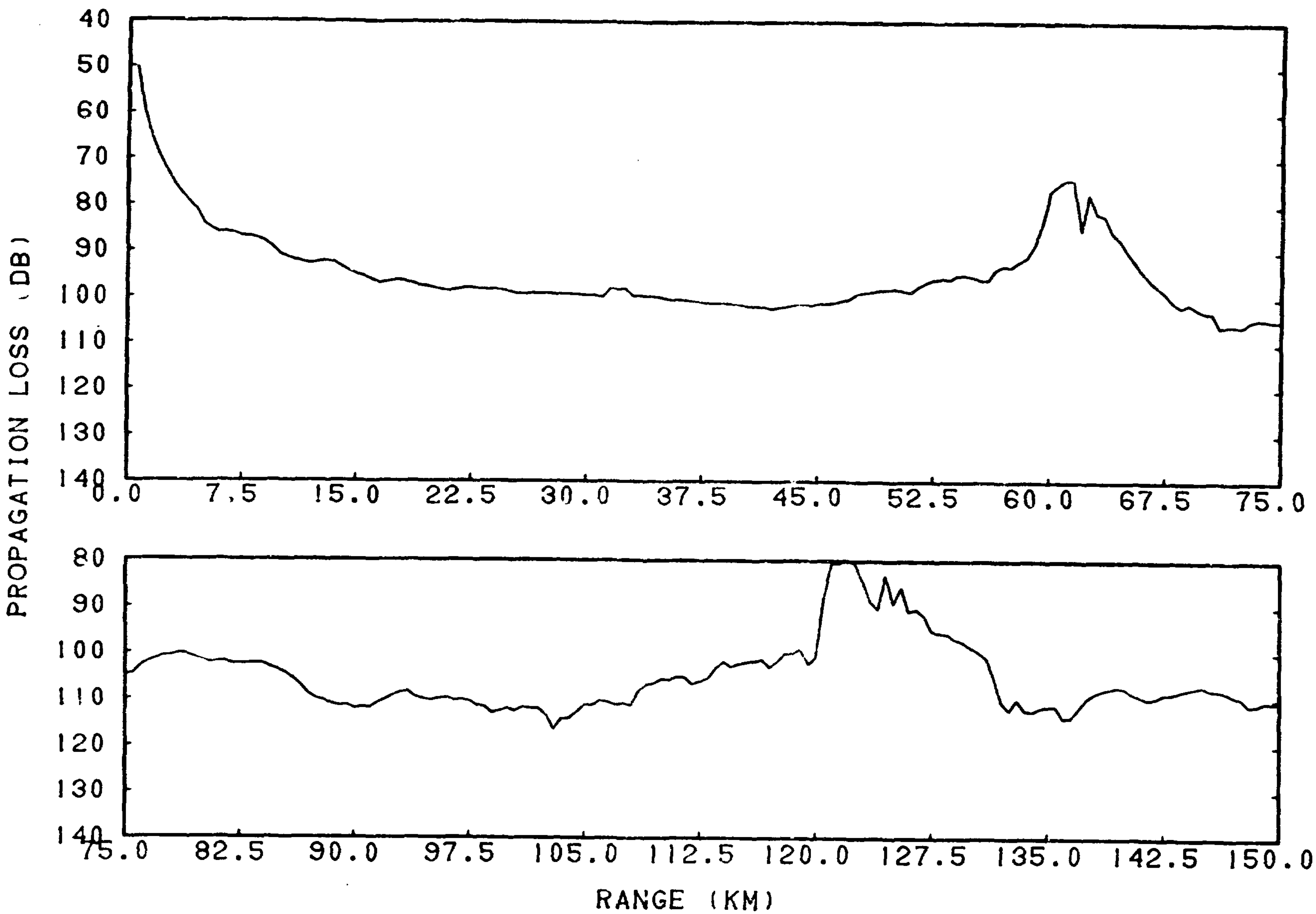
(C) Figure IIIE-19. Smoothed RAYMODE Coherent, Bottom Loss = MGS 7, Run 3S, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 30 Meters, Subtracted from LORAD Data, Run 3S, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 30 Meters



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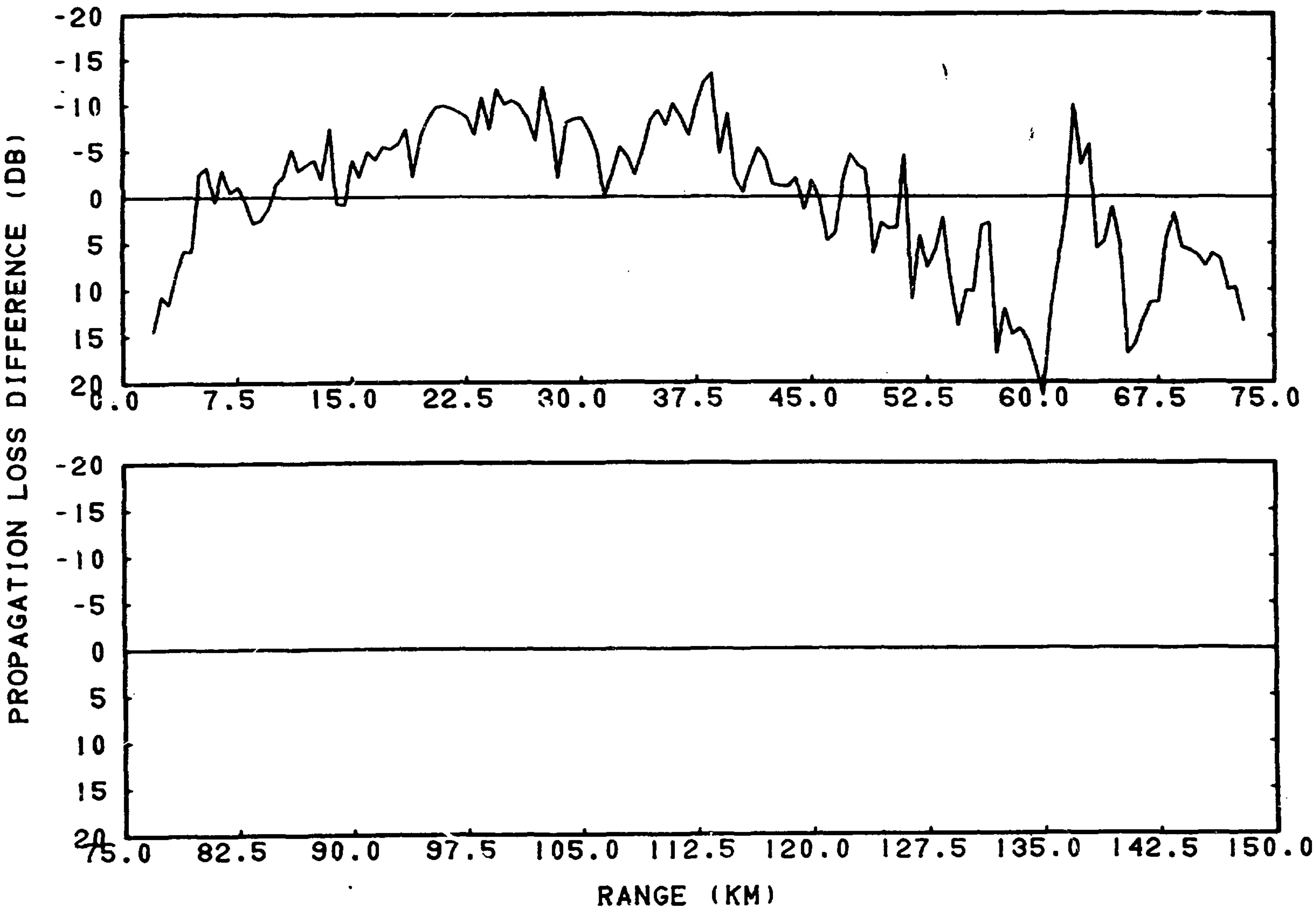
(C) Figure IIIE-20. RAYMODE Incoherent, Bottom Loss = MGS 7, Run 3S, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 30 Meters



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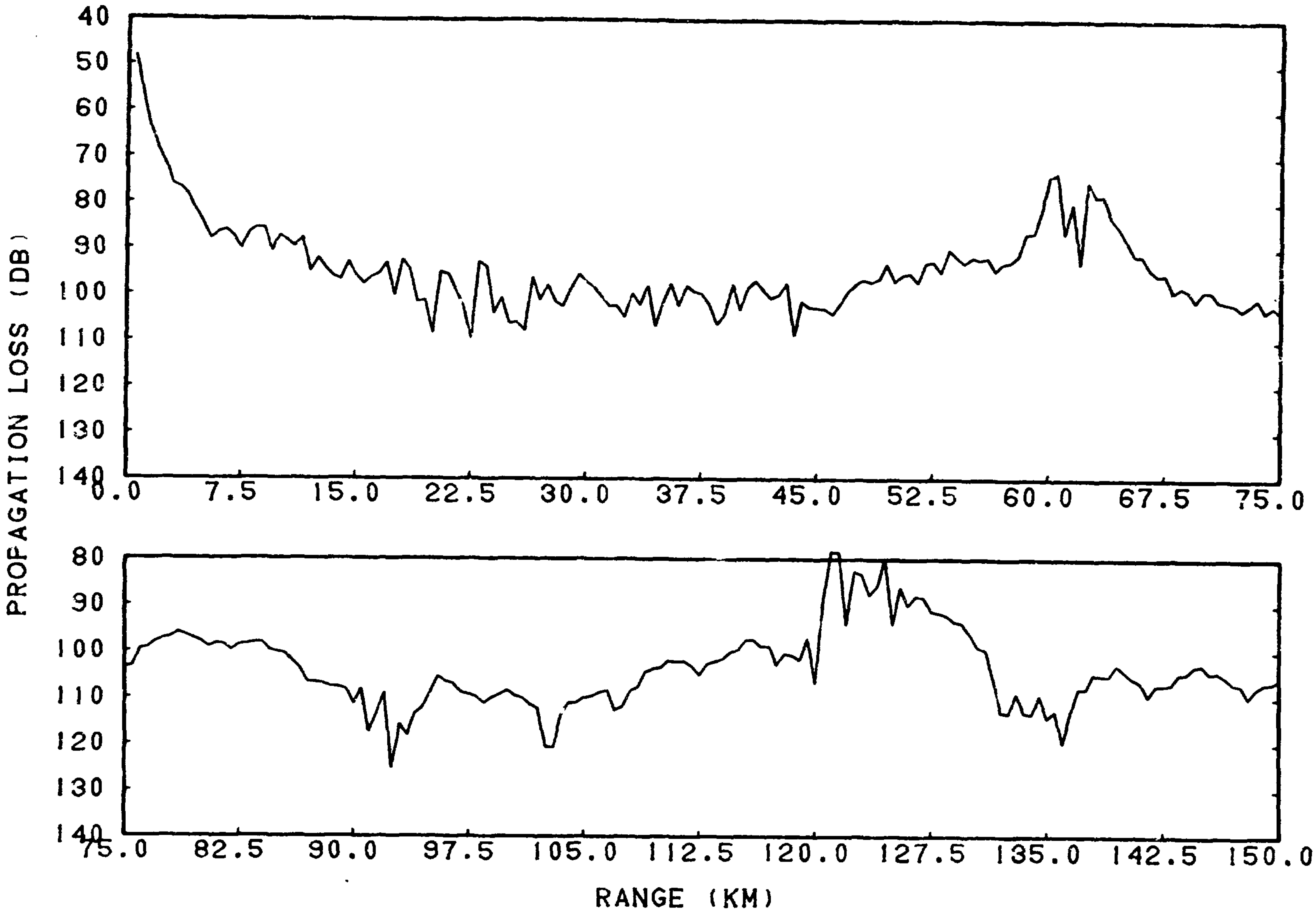
(C) Figure IIIE-21. RAYMODE Incoherent, Bottom Loss = MGS 7, Run 3S, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 30 Meters, Subtracted from LORAD Data, Run 3S, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 30 Meters



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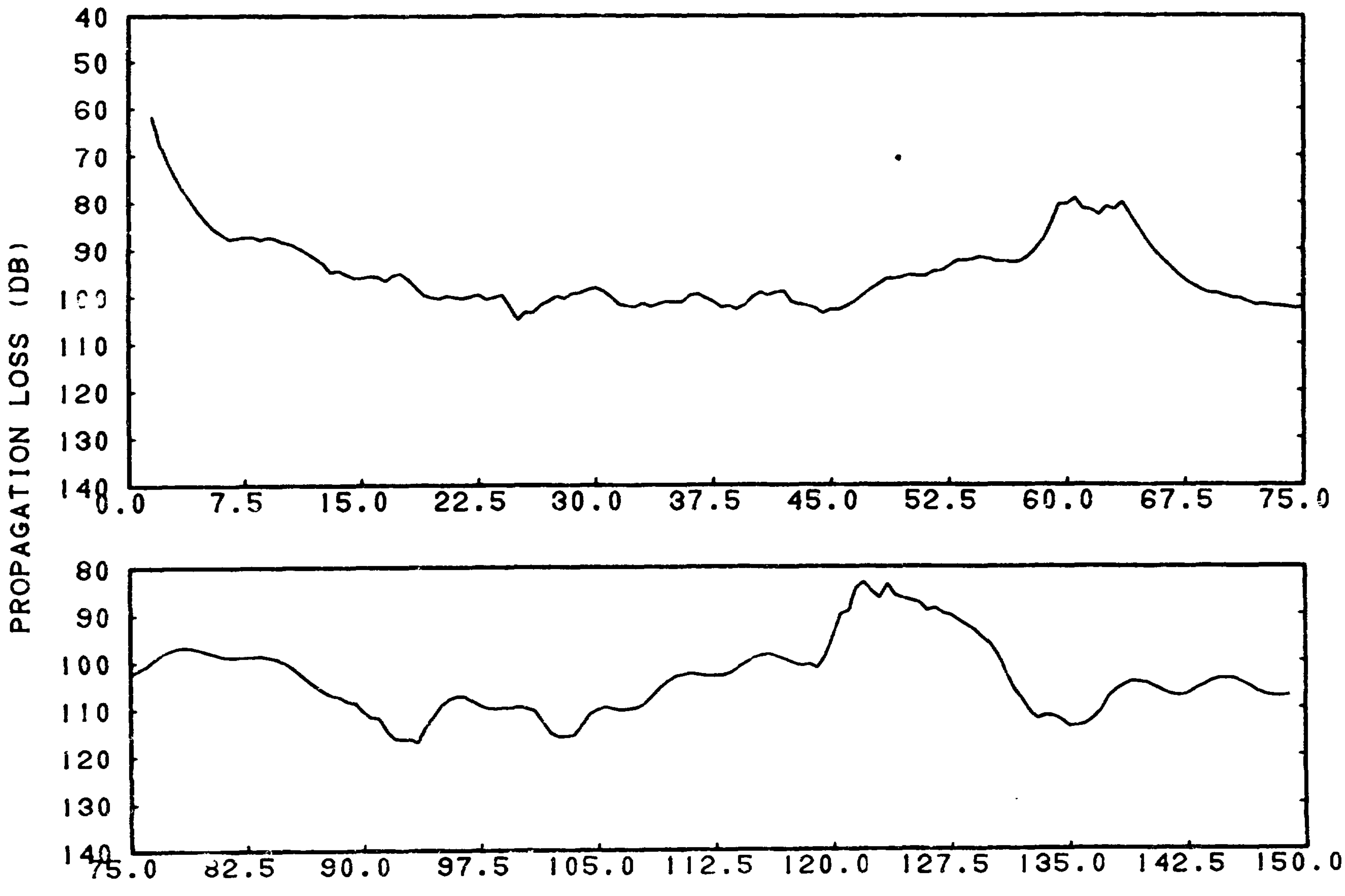
(C) Figure IIIE-22. RAYMODE Coherent, Bottom Loss = MGS 7, Run 6S, Frequency = 0.53 Kilometers, Source Depth = 15 Meters, Receiver Depth = 30 Meters



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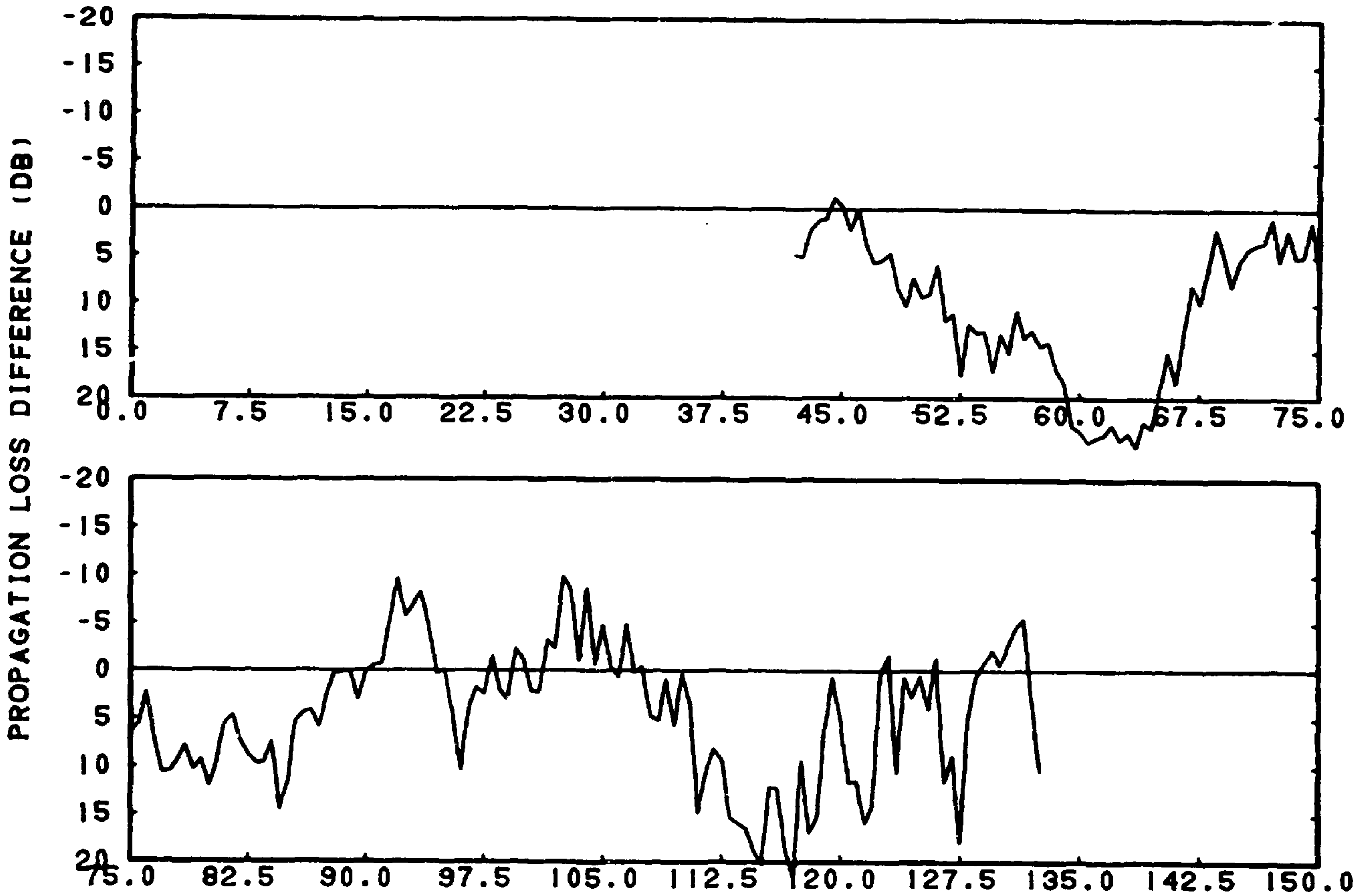
(C) Figure IIIE-23. RAYMODE Coherent, Bottom Loss = MGS 7, Run 6S, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 30 Meters, Sliding Averages of 5 Points (2.00 Kilometers)



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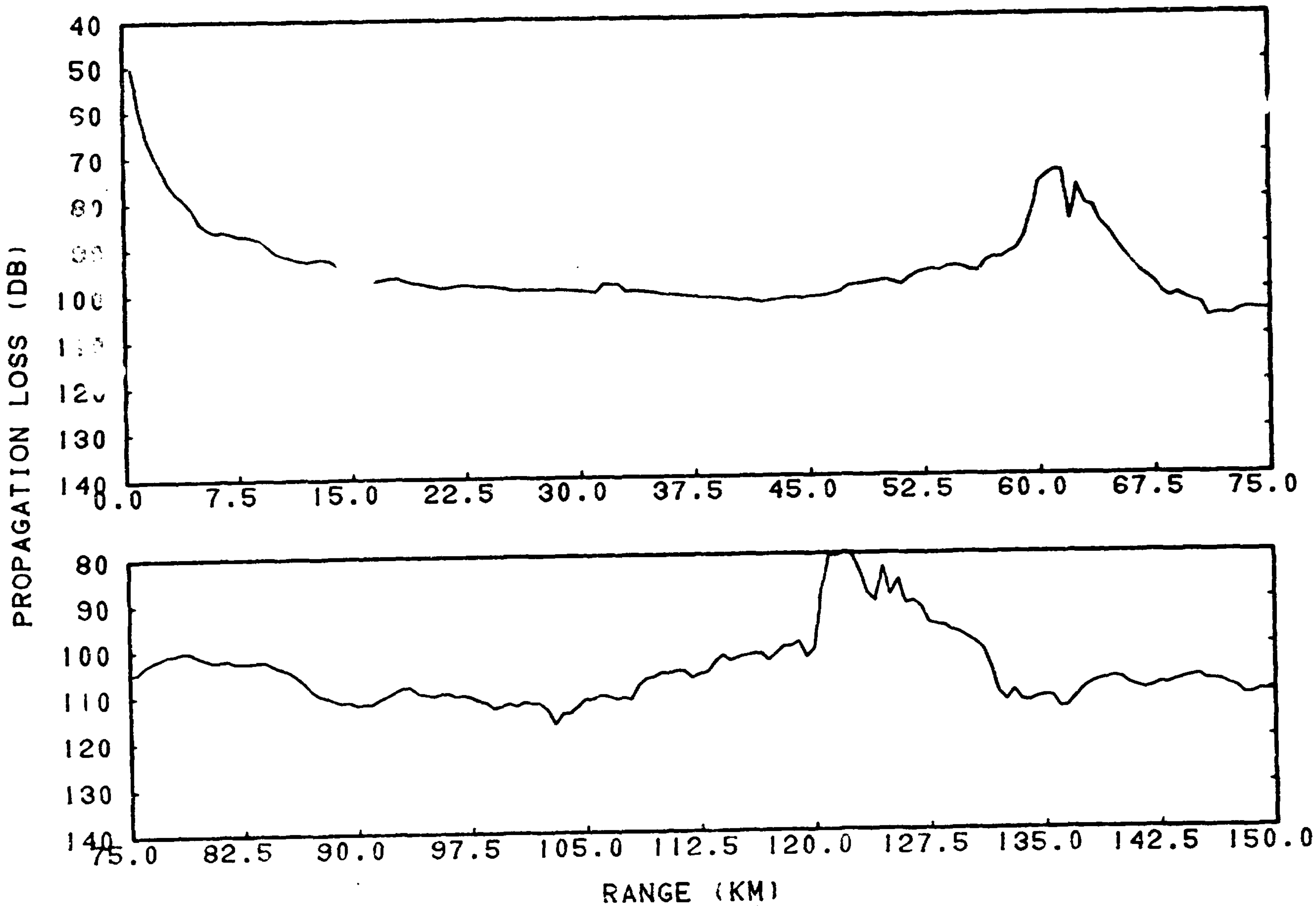
(C) Figure IIIE-24. Smoothed RAYMODE Coherent, Bottom Loss = MGS 7, Run 6S, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 30 Meters, Subtracted from LORAD Data, Run 6S, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 30 Meters



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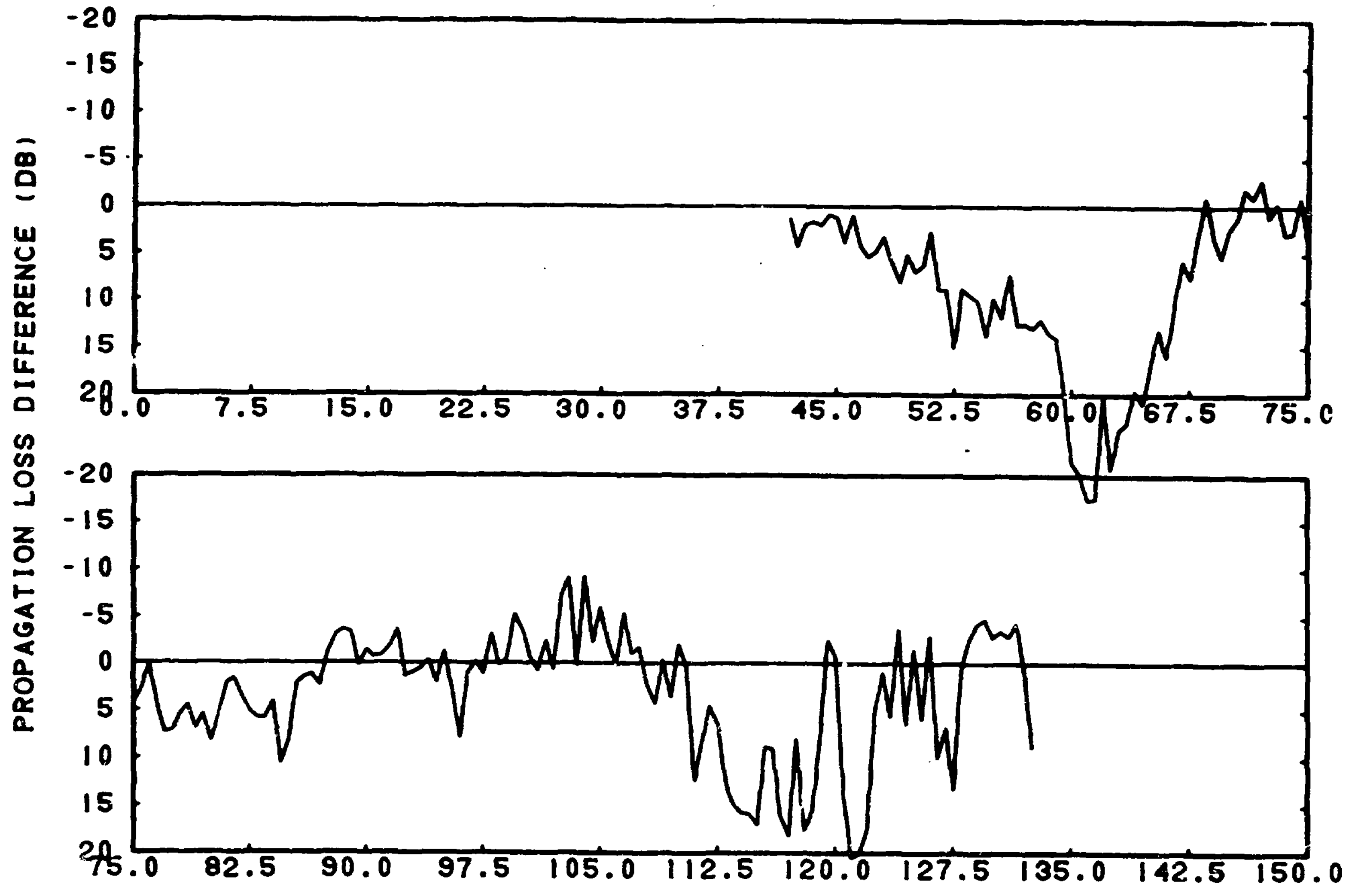
(C) Figure IIIE-25. RAYMODE Incoherent, Bottom Loss = MGS 7, Run 6S, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 30 Meters



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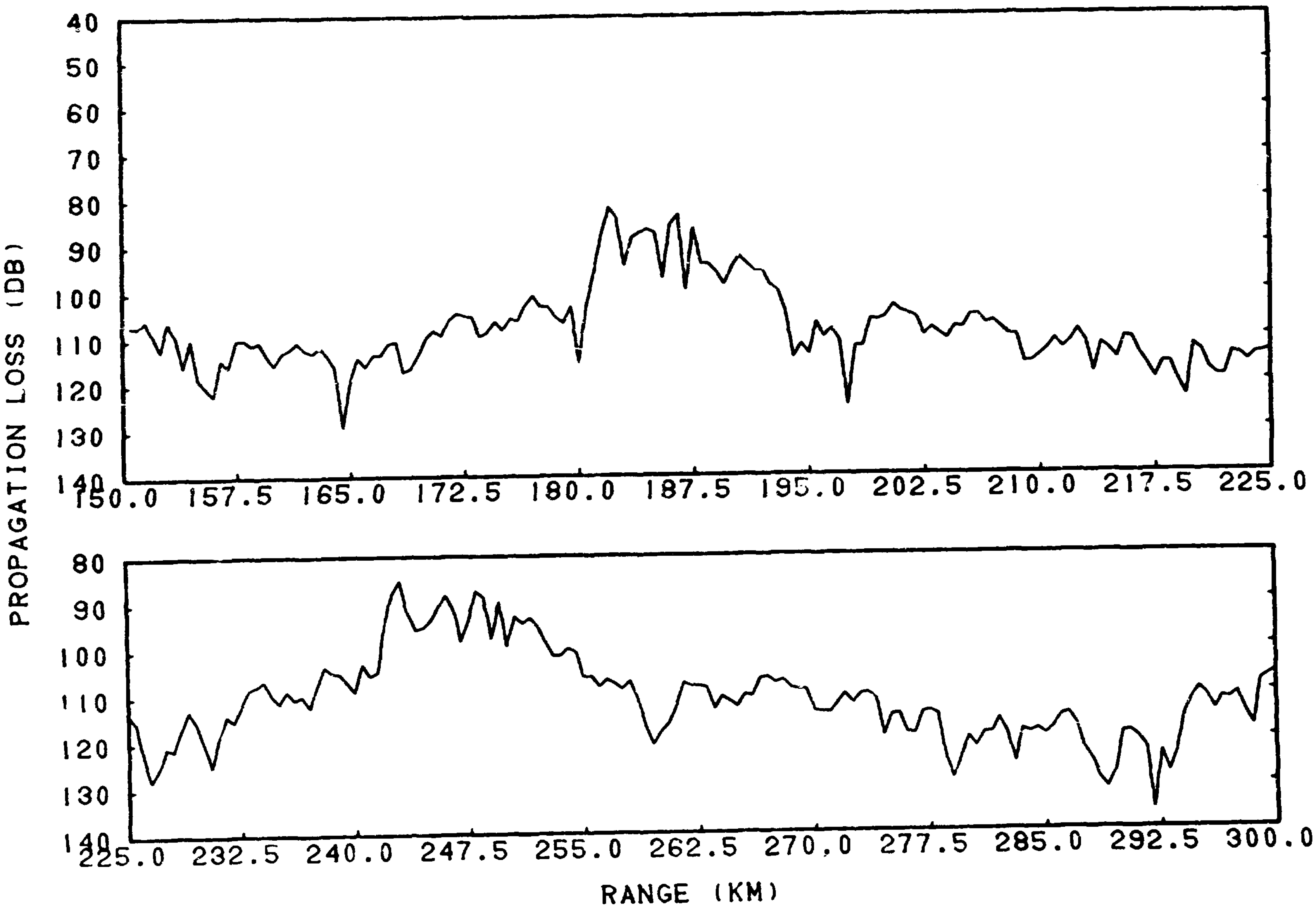
(C) Figure IIIE-26. RAYMODE Incoherent, Bottom Loss = MGS 7, Run 6S, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 30 Meters, Subtracted from LORAD Data, Run 6S, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 30 Meters



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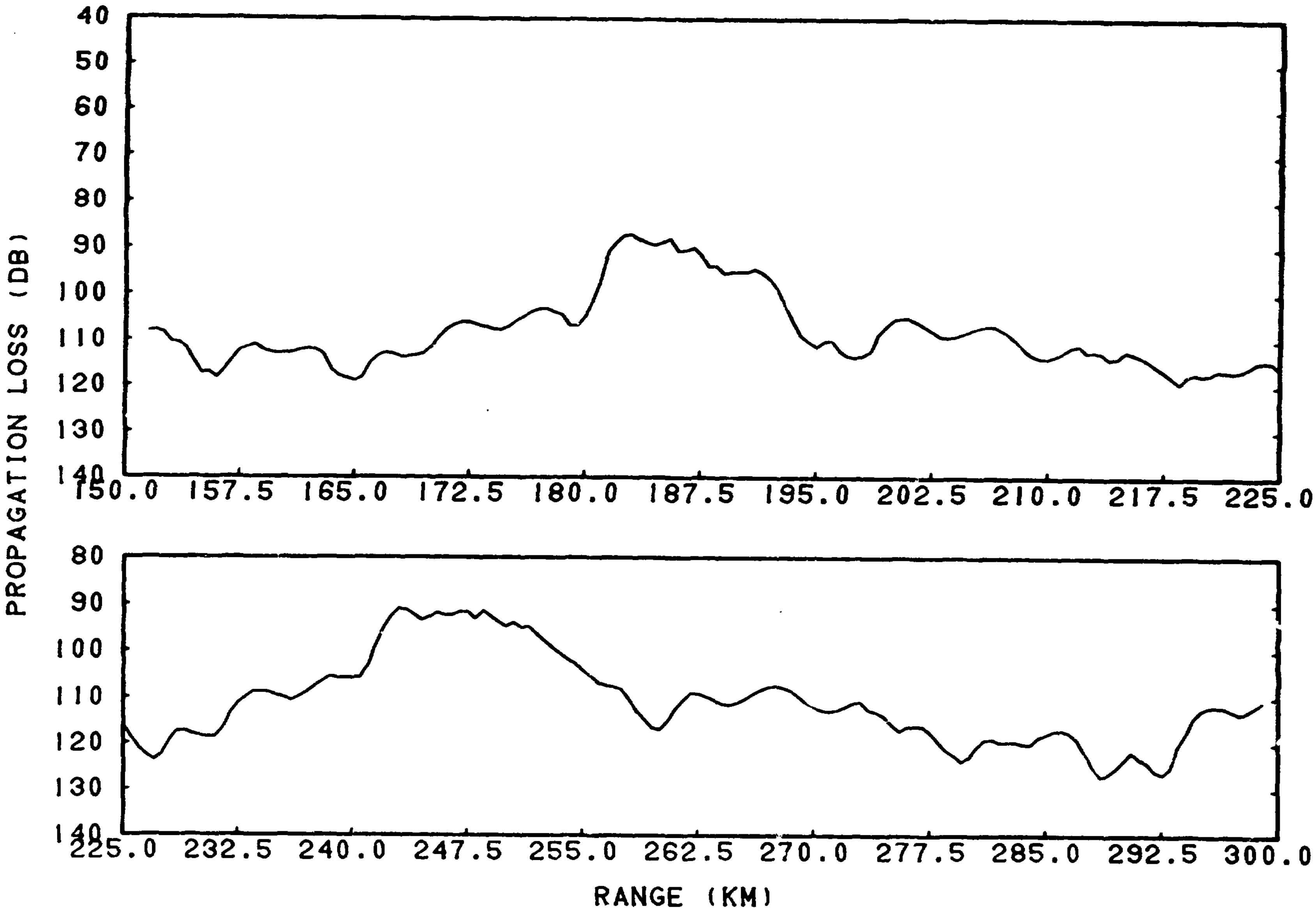
(C) Figure IIIE-27. RAYMODE Coherent, Bottom Loss = MGS 7, Run 8S, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 30 Meters



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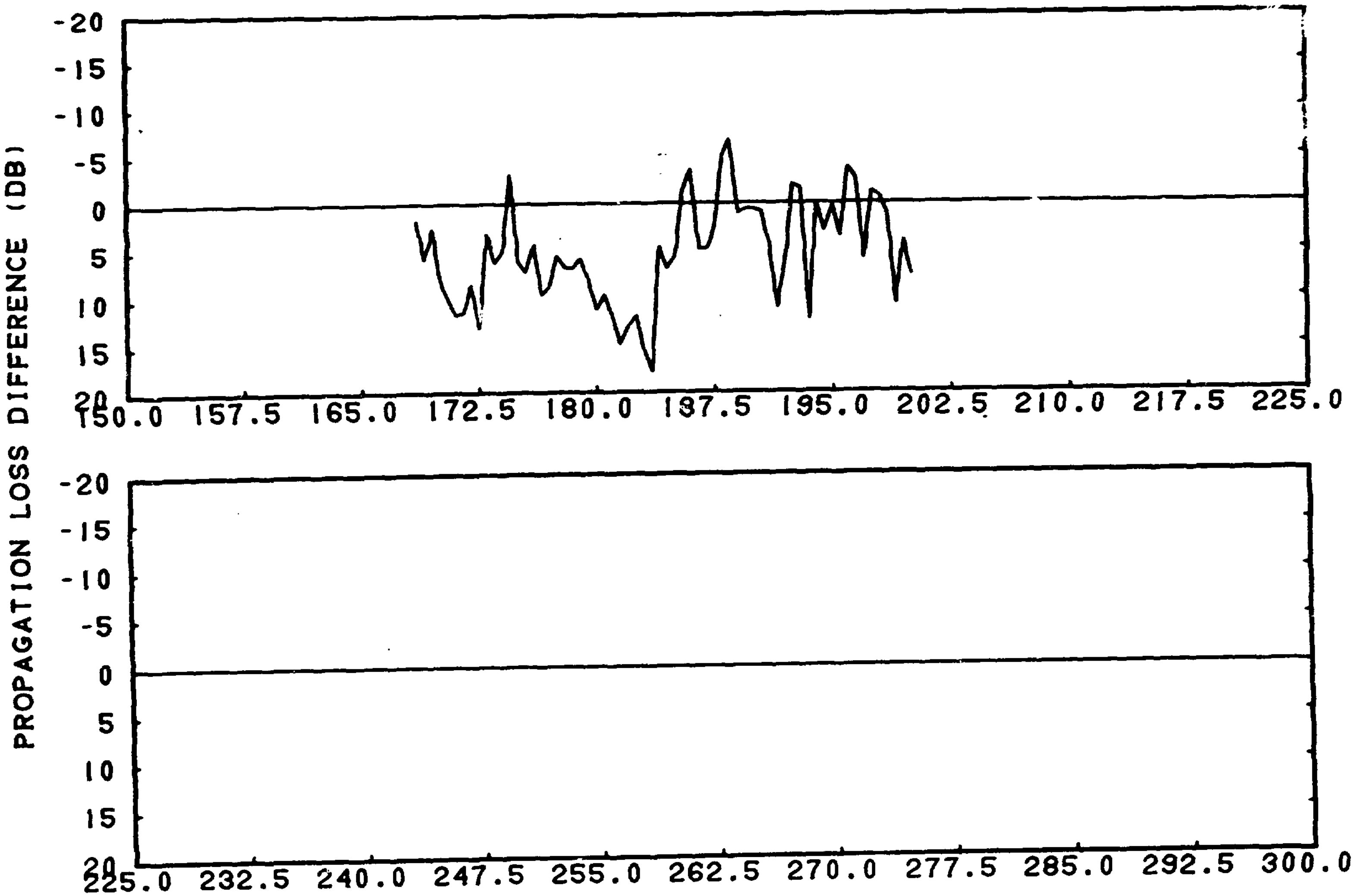
(C) Figure IIIE-28. RAYMODE Coherent, Bottom Loss = MGS 7, Run 8S, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 30 Meters, Sliding Averages of 5 Points (2.00 Kilometers)



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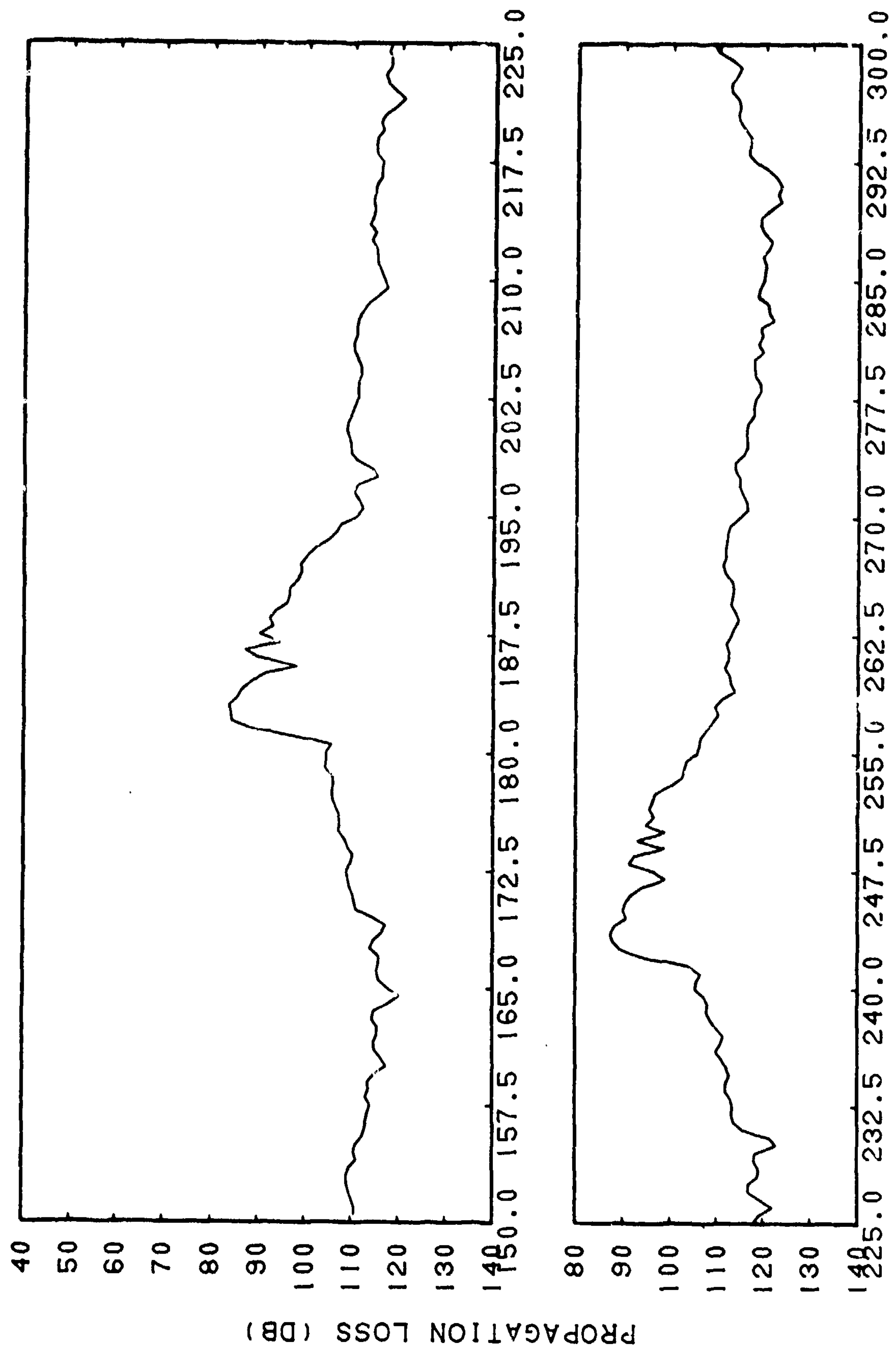
(C) Figure IIIE-29. Smoothed RAYMODE Coherent, Bottom Loss = MGS 7, Run 8S, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 30 Meters, Subtracted from LORAD Data, Run 8S, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth 30 Meters



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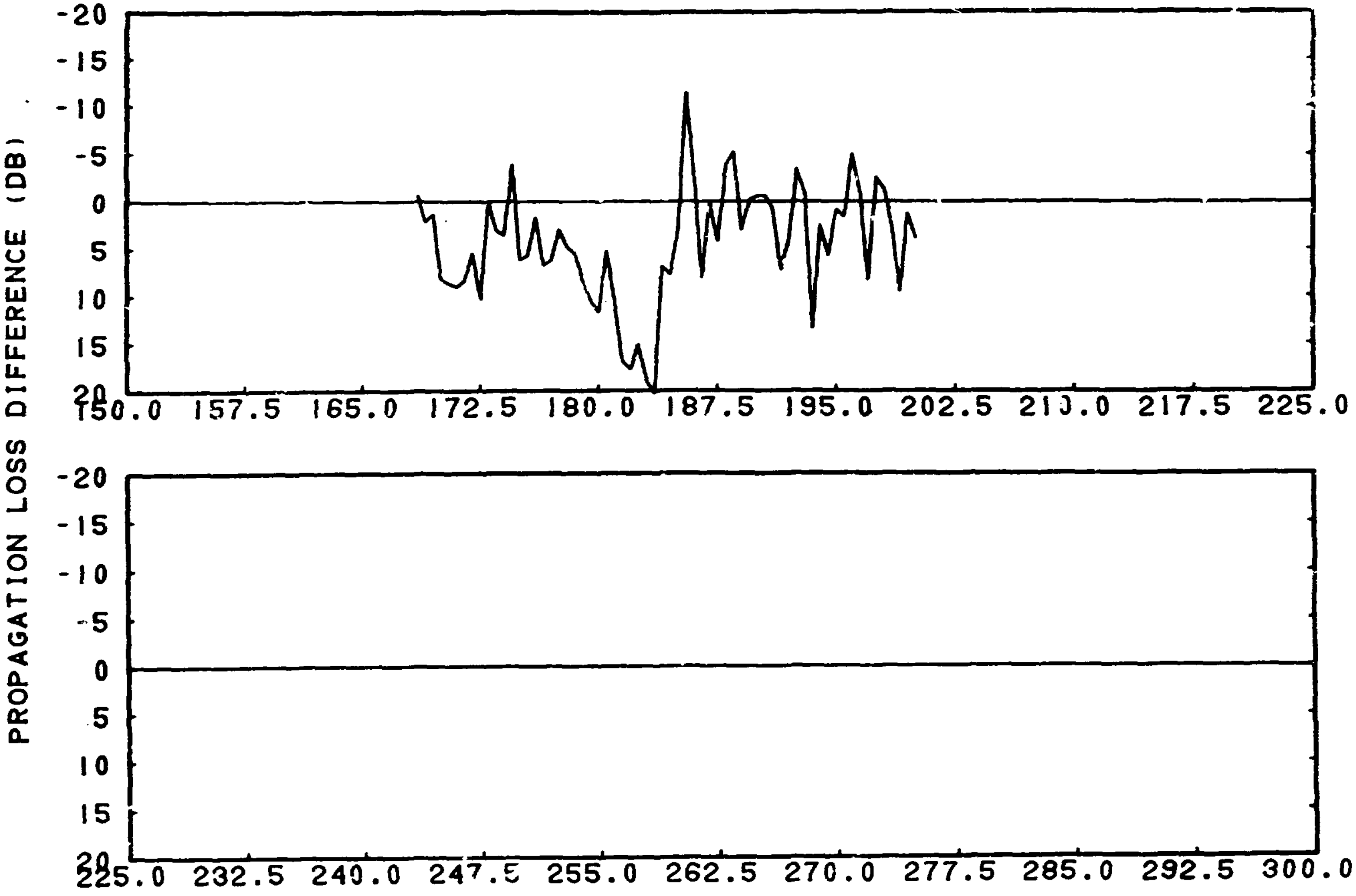
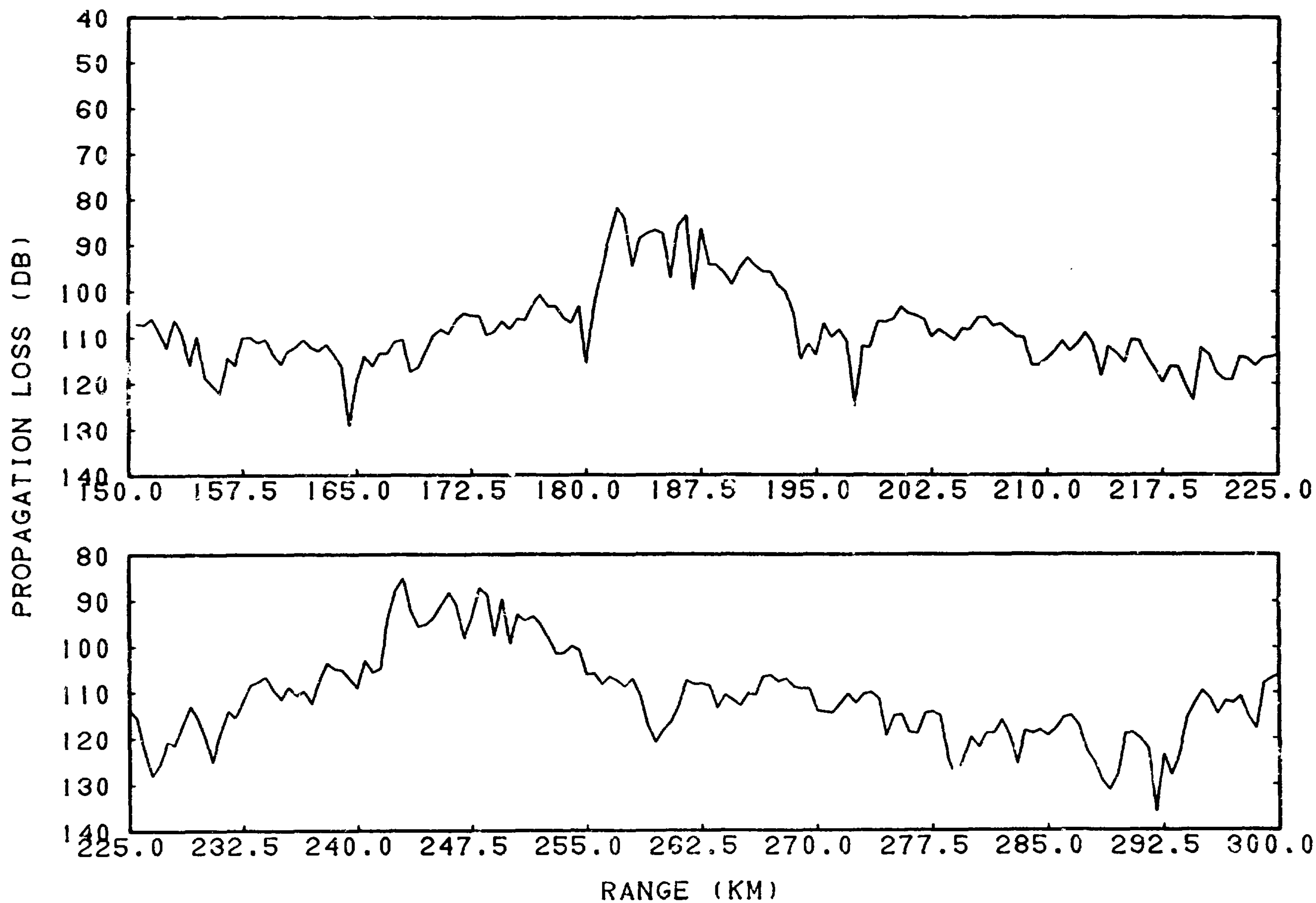
(C) Figure IIIE-30. RAYMODE Incoherent, Bottom Loss = MGS 7, Run 8S, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 30 Meters



(C) Figure IIIE-31. RAYMODE Incoherent, Bottom Loss = MGS 7, Run 8S, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 30 Meters, Subtracted from LORAD Data, Run 8S, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 30 Meters



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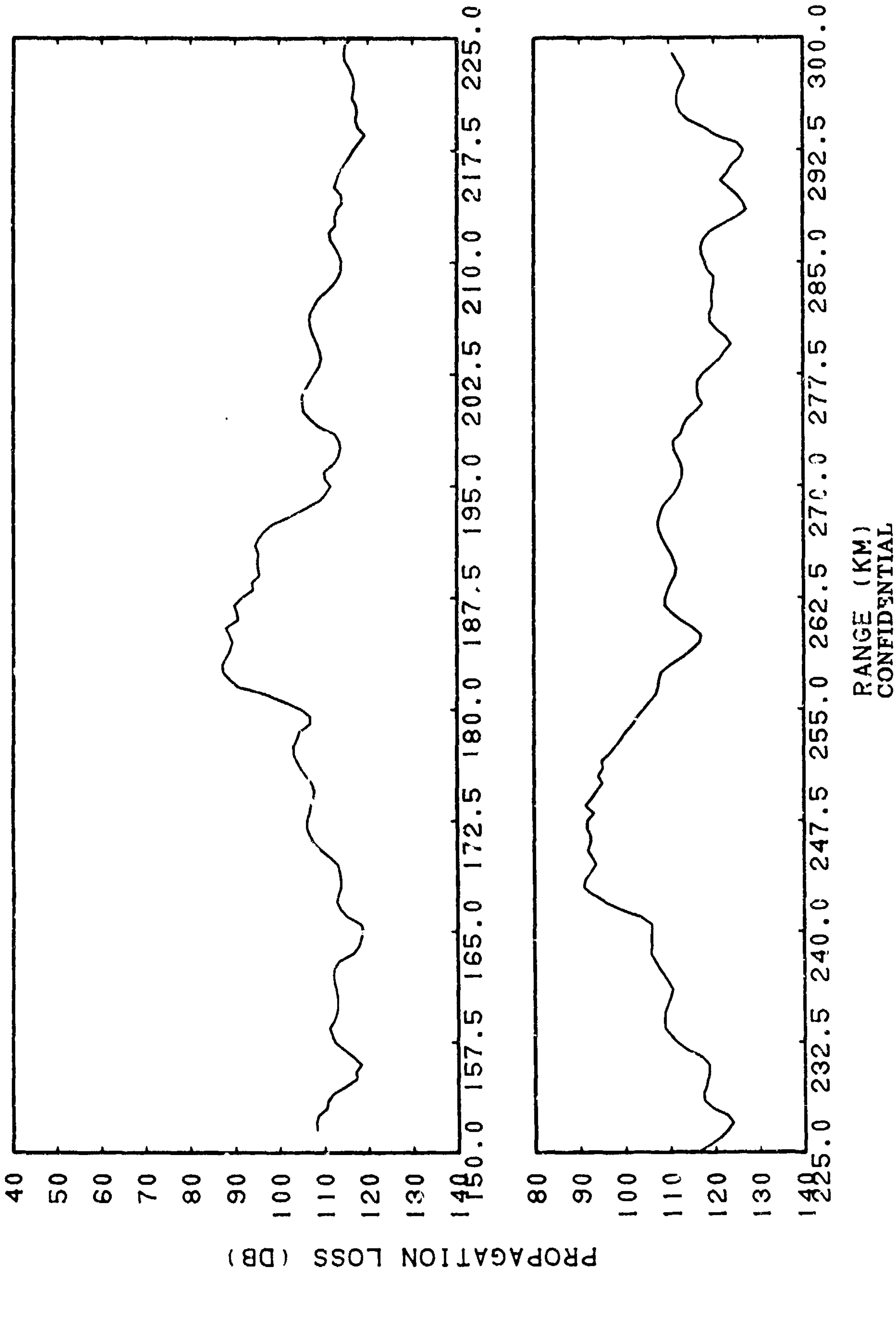
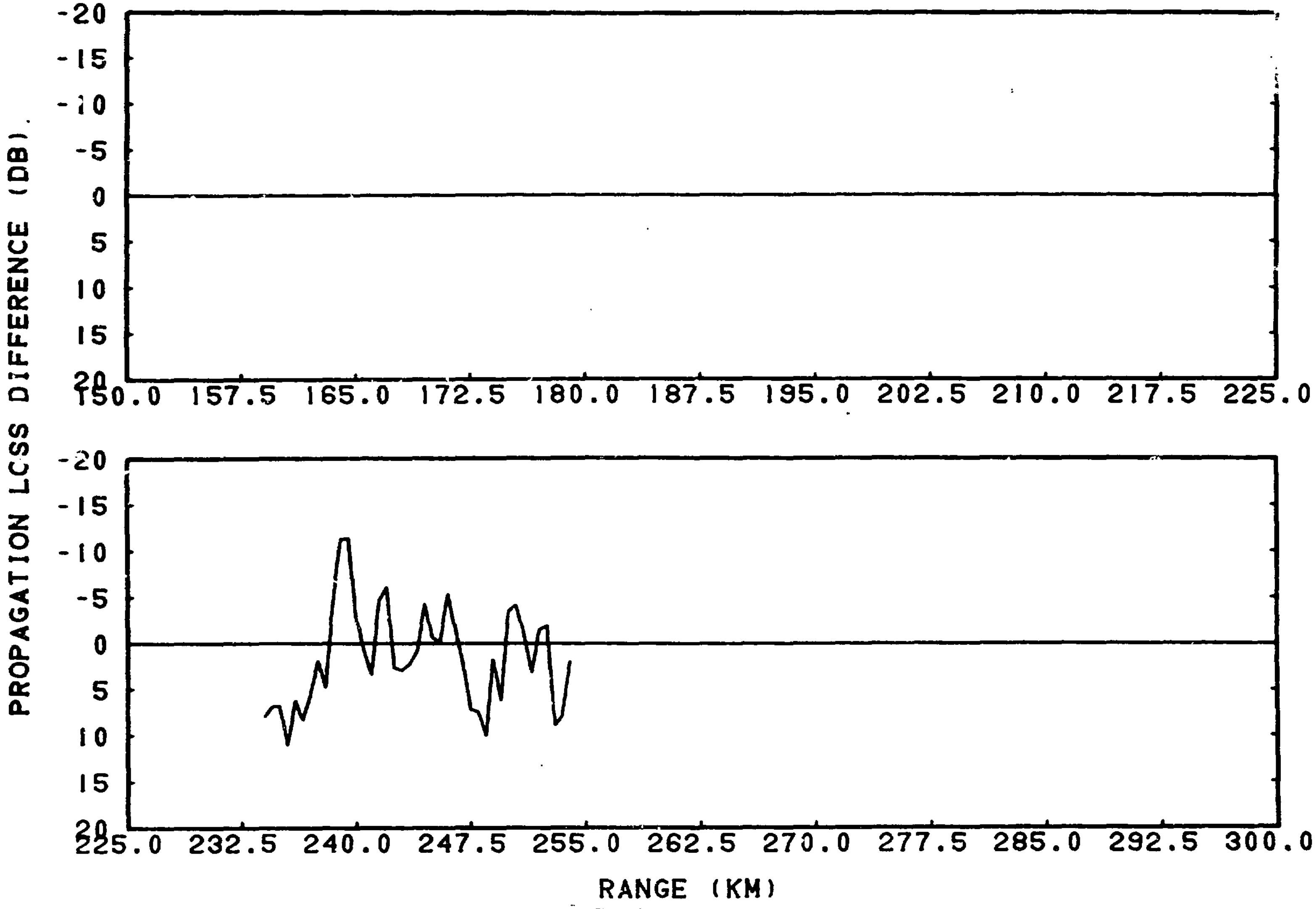
(C) Figure IIIE-32. RAYMODE Coherent, Bottom Loss = MGS 7, Run 10S, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 30 Meters



(C) Figure IIIE-33. RAYMODE Coherent, Bottom Loss = MGS 7, Run 10S, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 30 Meters, Sliding Averages of 5 Points (2.00 Kilometers)



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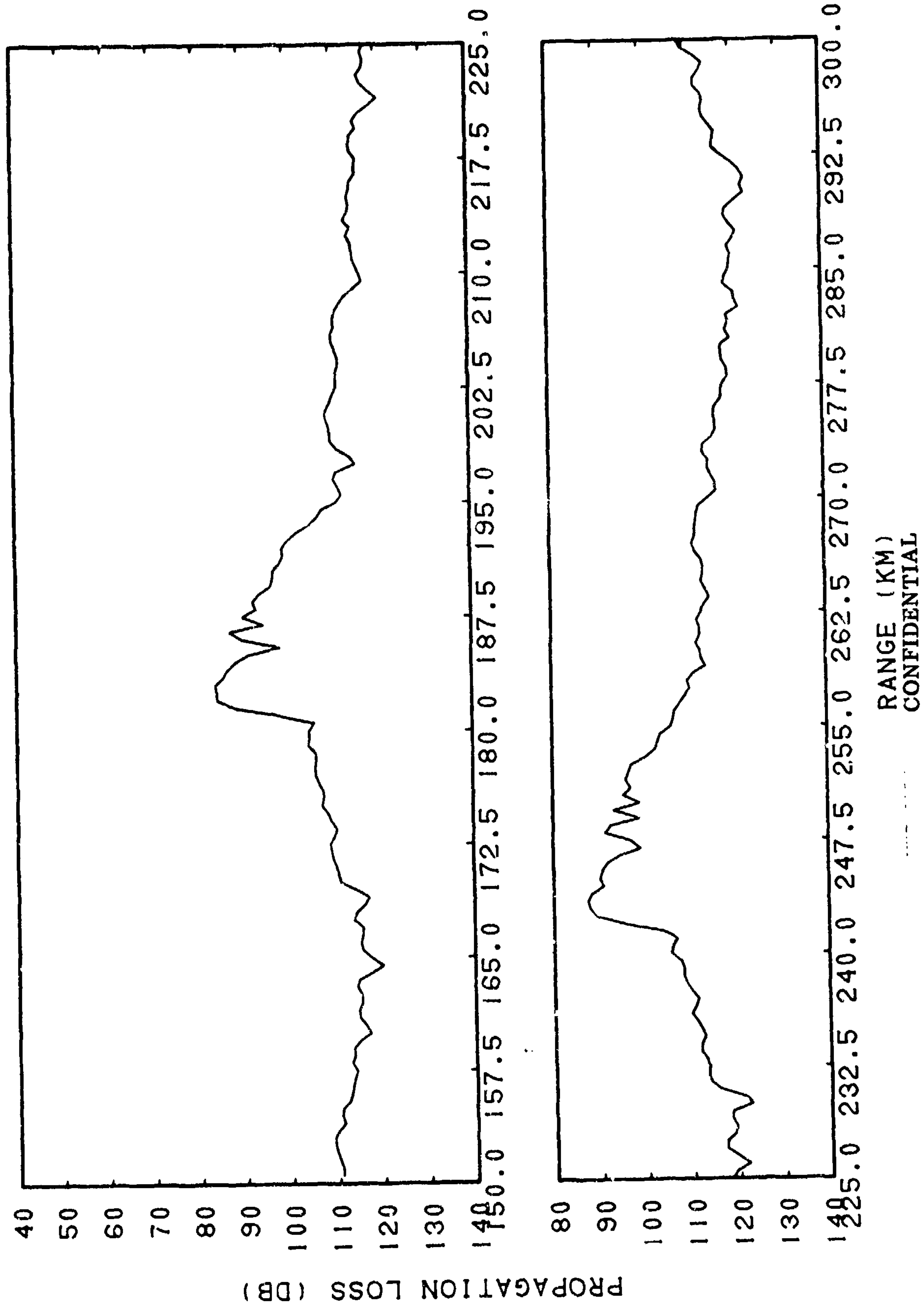
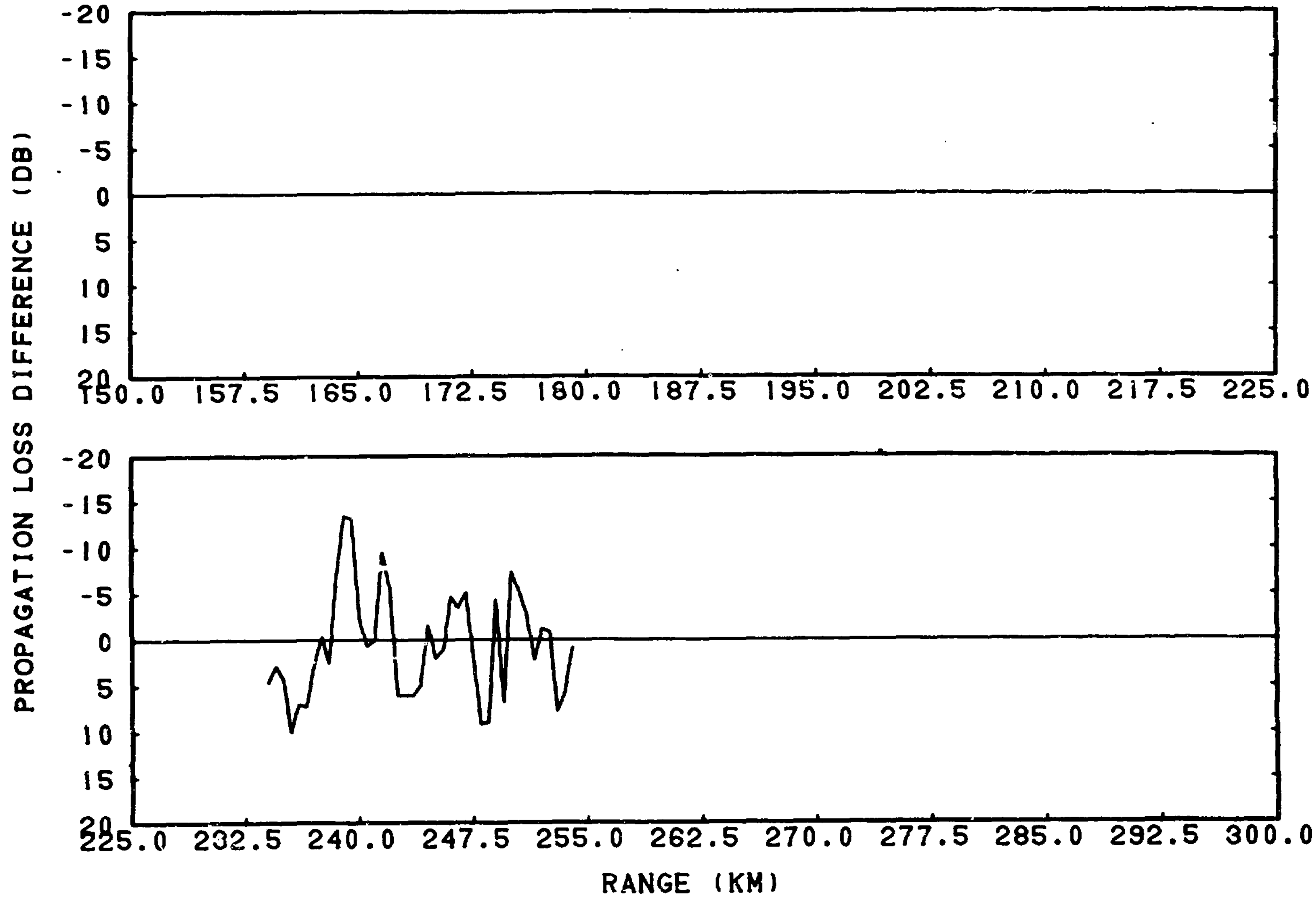
(C) Figure IIIE-34. Smoothed RAYMODE Coherent, Bottom Loss = MGS 7, Run 10S, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 30 Meters, Subtracted from LORAD Data, Run 10S, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 30 Meters



(C) Figure IIIE-35. RAYMODE Incoherent, Bottom Loss = MGS 7, Run 10S, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 30 Meters



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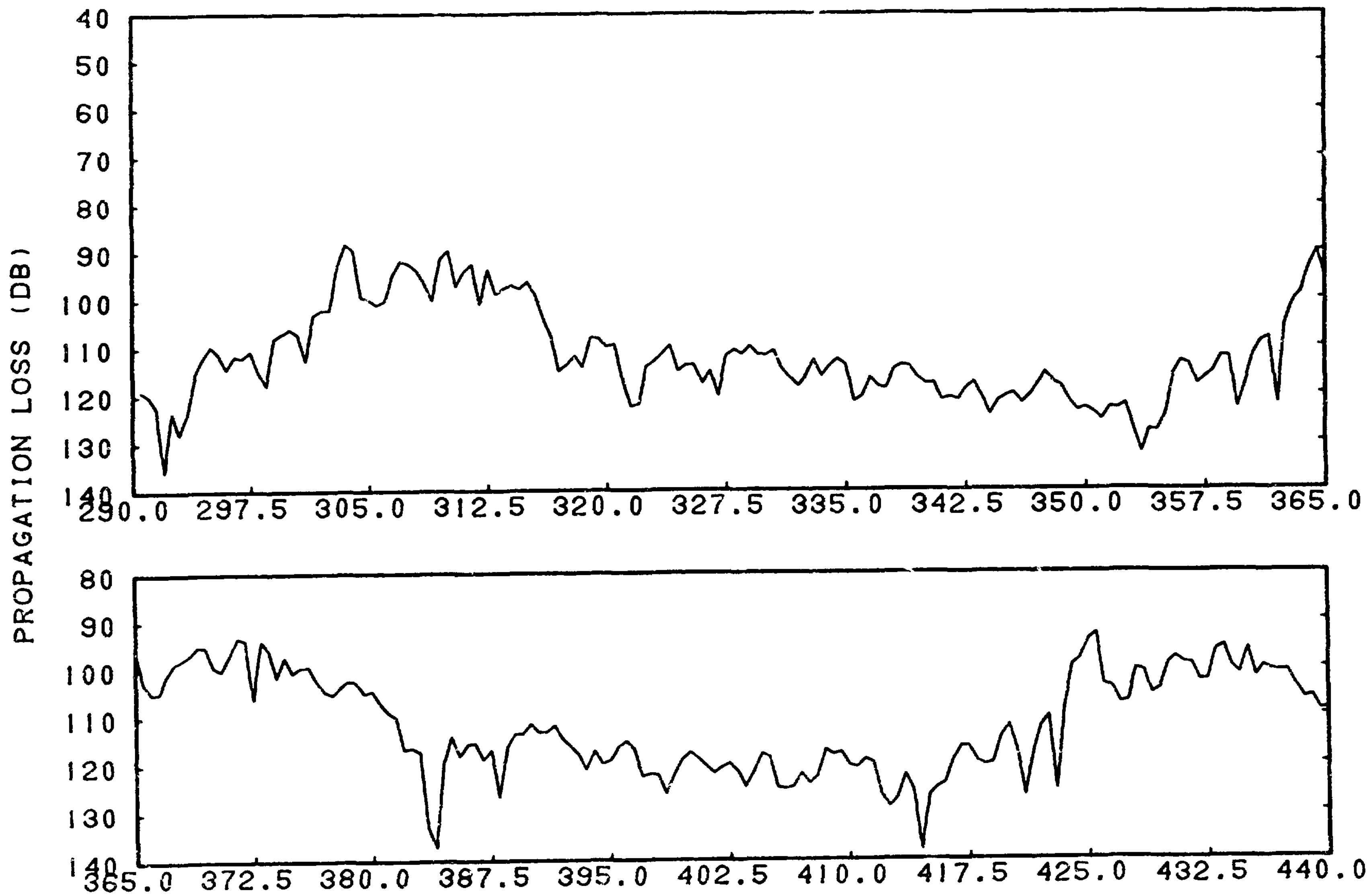
(C) Figure IIIE-36. RAYMODE Incoherent, Bottom Loss = MGS 7, Run 10S, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 30 Meters, Subtracted from LORAD Data, Run 10S, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 30 Meters



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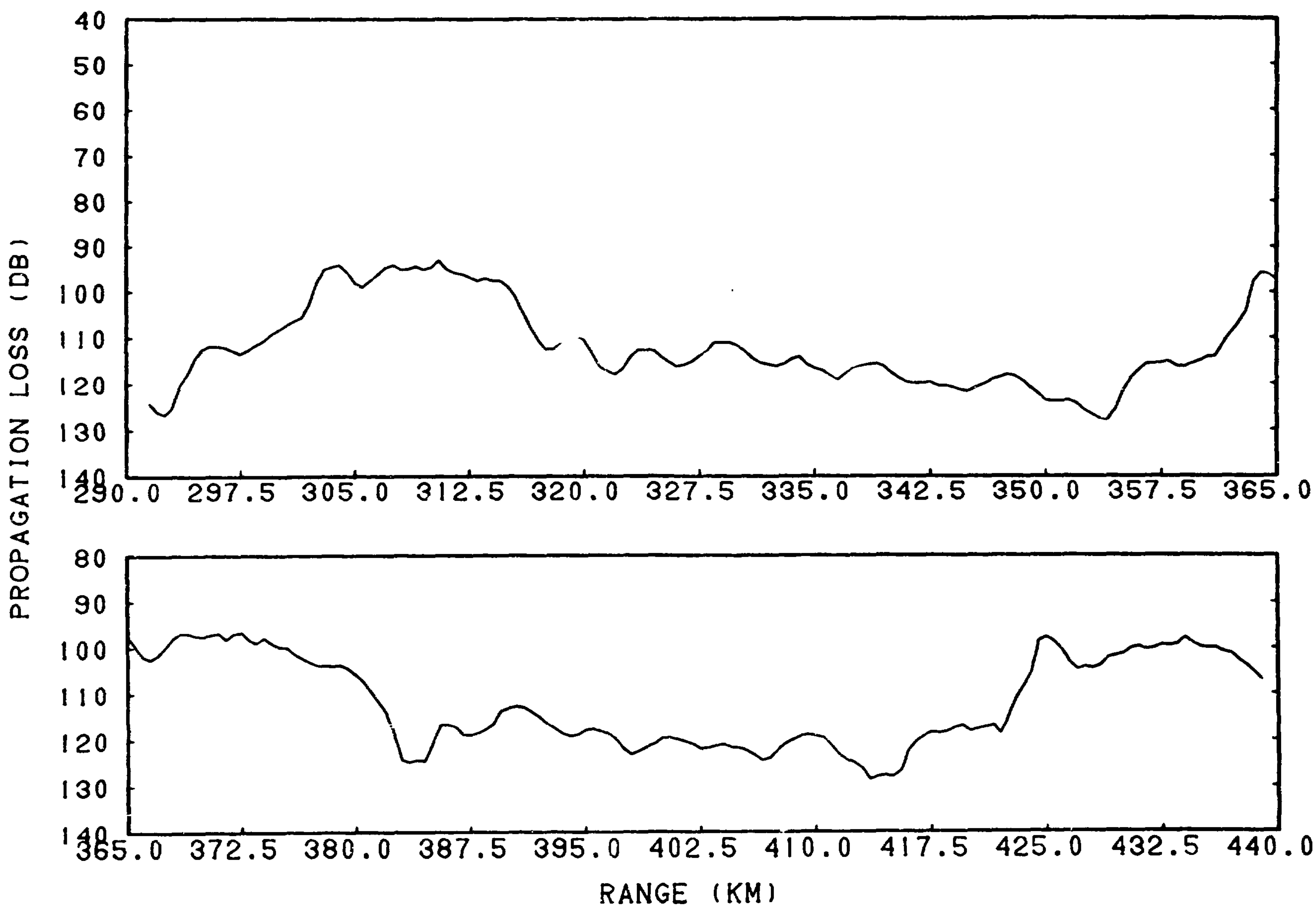
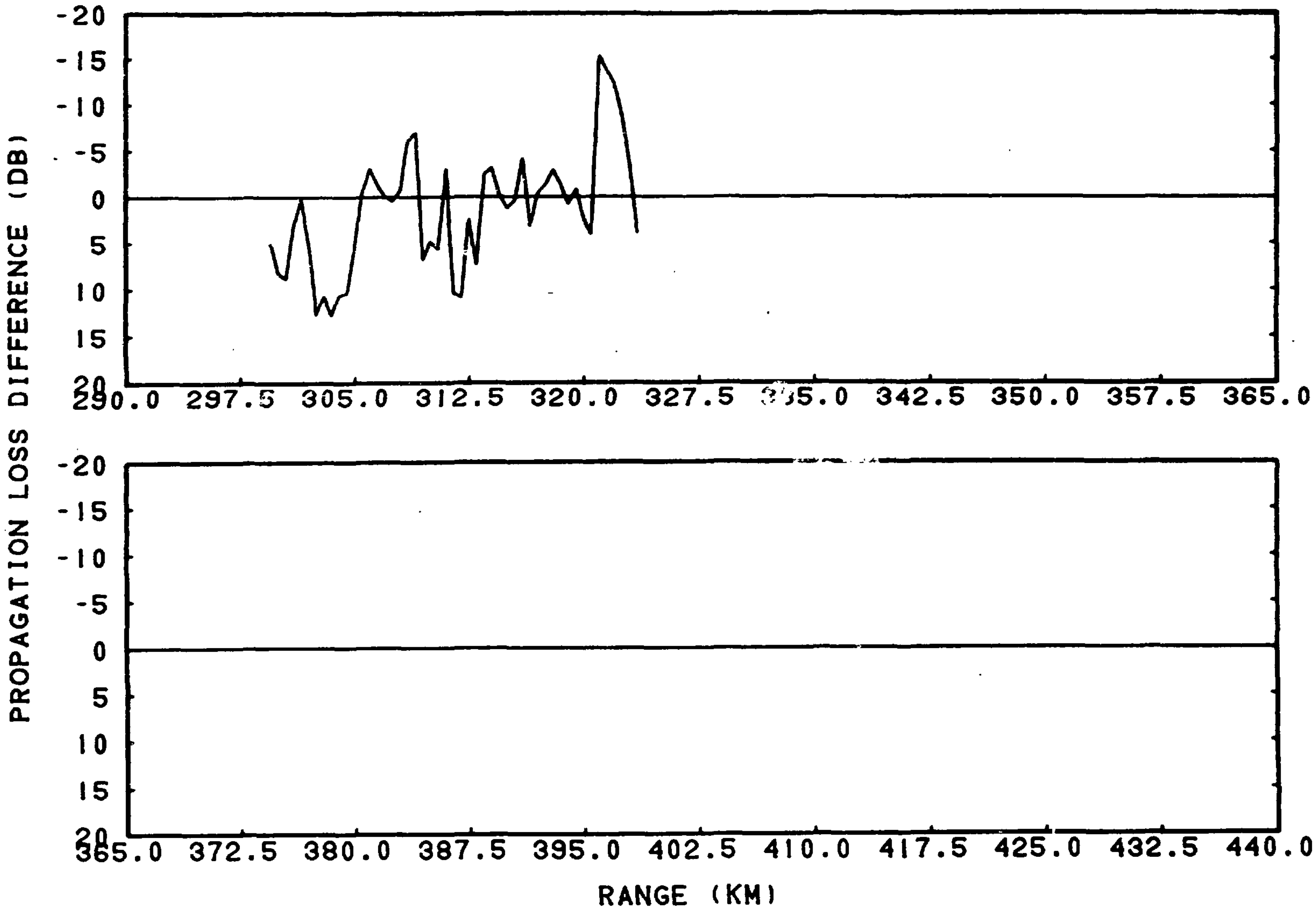
(C) Figure IIIE-37. RAYMODE Coherent, Bottom Loss = MGS 7, Run 12S, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 30 Meters



(C) Figure IIIE-38. RAYMODE Coherent, Bottom Loss = MGS 7, Run 12S, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 30 Meters, Sliding Averages of 5 Points (2.00 Kilometer)



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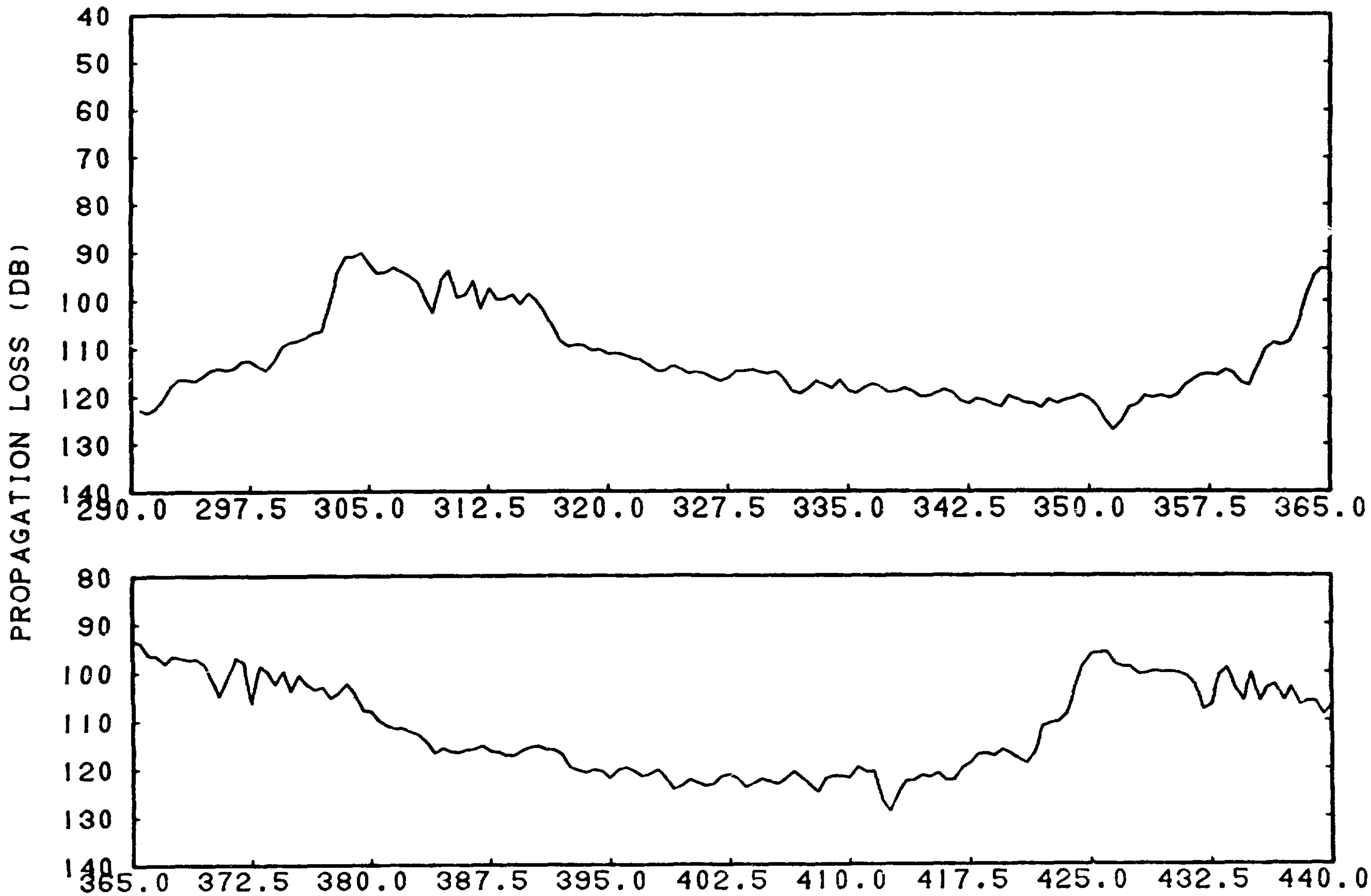
(C) Figure IIIE-39. Smoothed RAYMODE Coherent, Bottom Loss = MGS 7, Run 12S, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 30 Meters, Subtracted from LORAD Data, Run 12S, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 30 Meters



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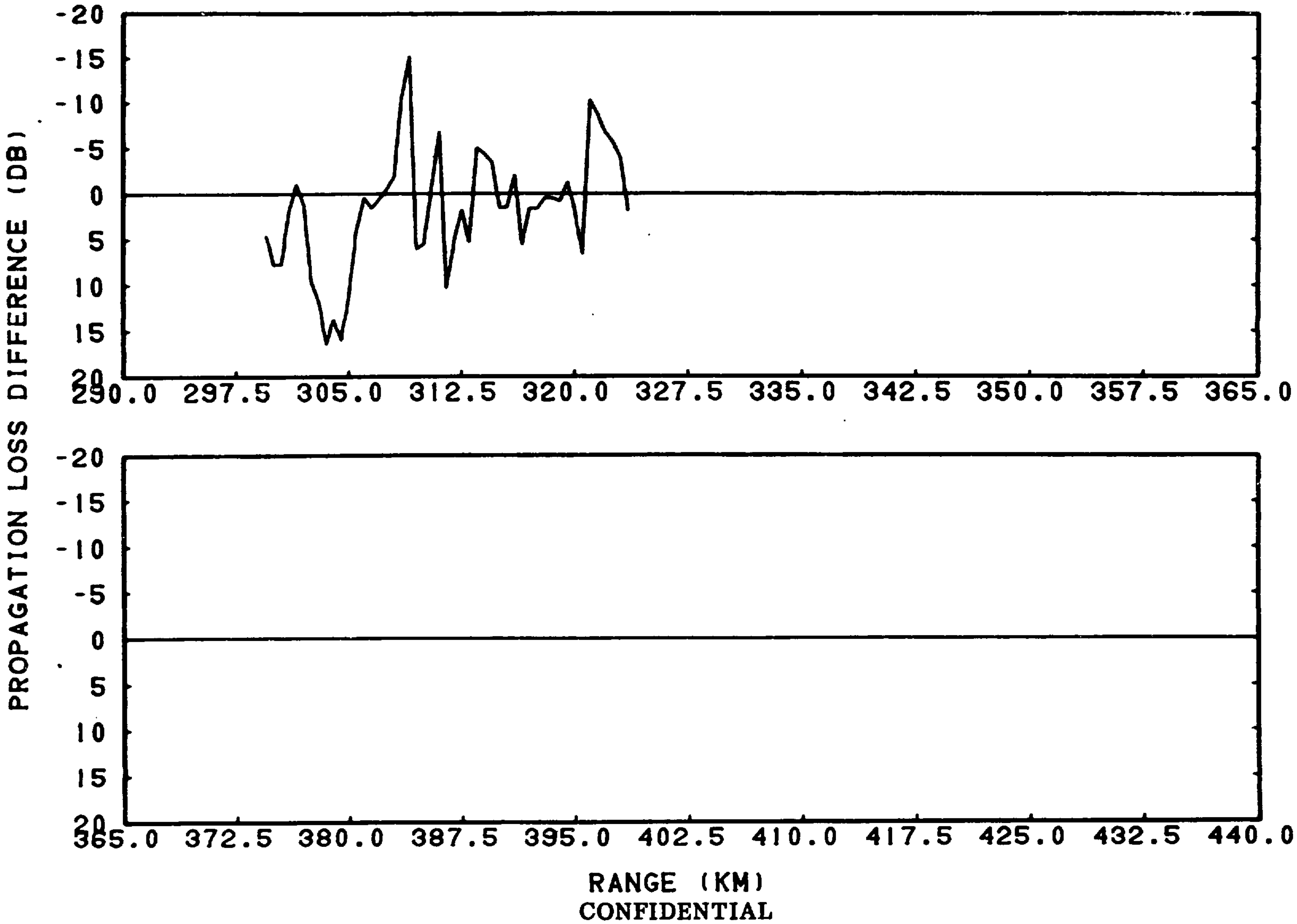
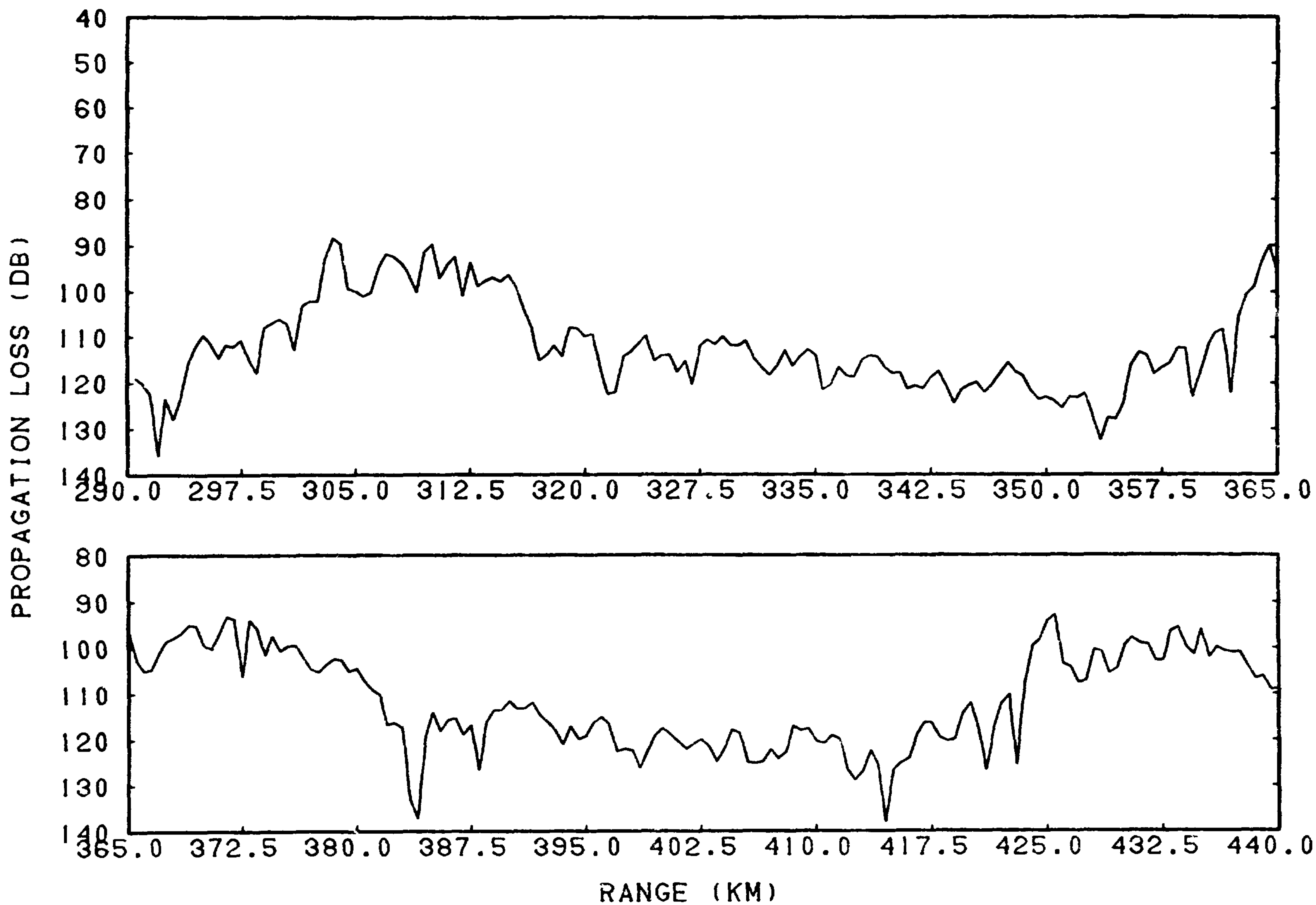
(C) Figure IIIE-40. RAYMODE Incoherent, Bottom Loss = MGS 7, Run 12S, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 30 Meters



(C) Figure IIIE-41. RAYMODE Incoherent, Bottom Loss = MGS 7, Run 12S, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 30 Meters, Subtracted from LORAD Data, Run 12S, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth 30 Meters



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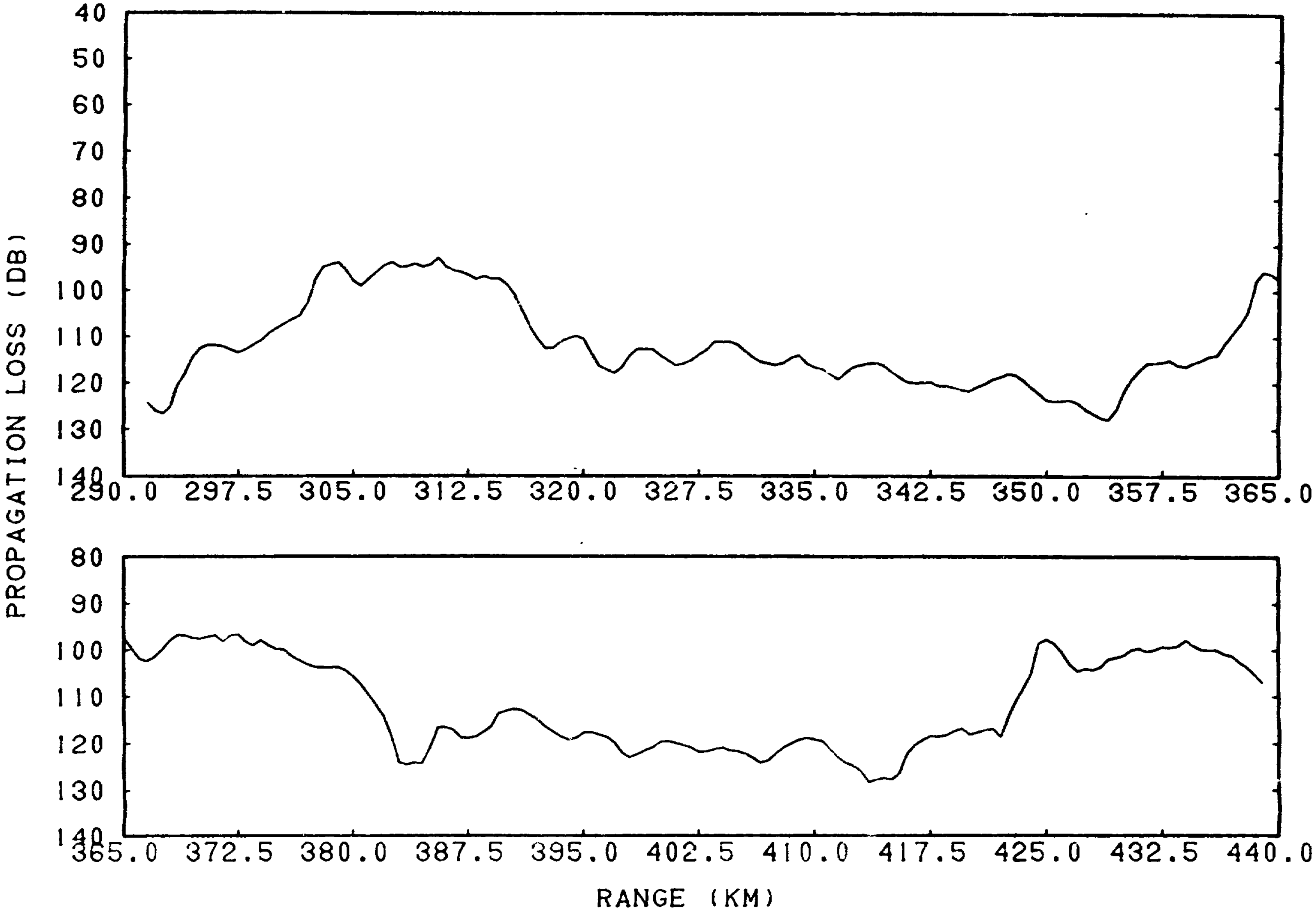
(C) Figure IIIE-42. RAYMODE Coherent, Bottom Loss = MGS 7, Run 14S, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 30 Meters



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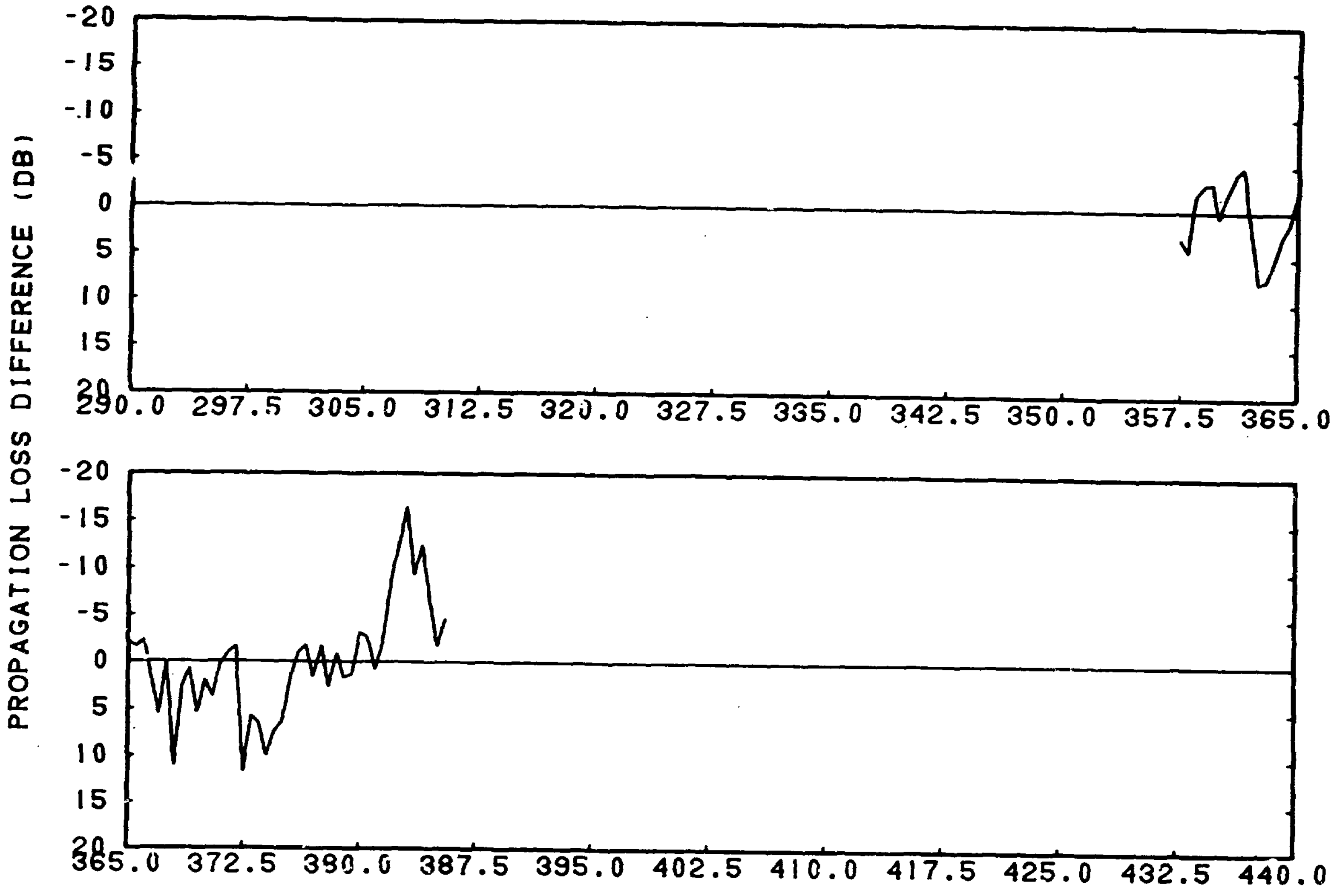
(C) Figure IIIE-43. RAYMODE Coherent, Bottom Loss = MGS 7, Run 14S, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 30 Meters, Sliding Averages of 5 Points (2.00 Kilometers)



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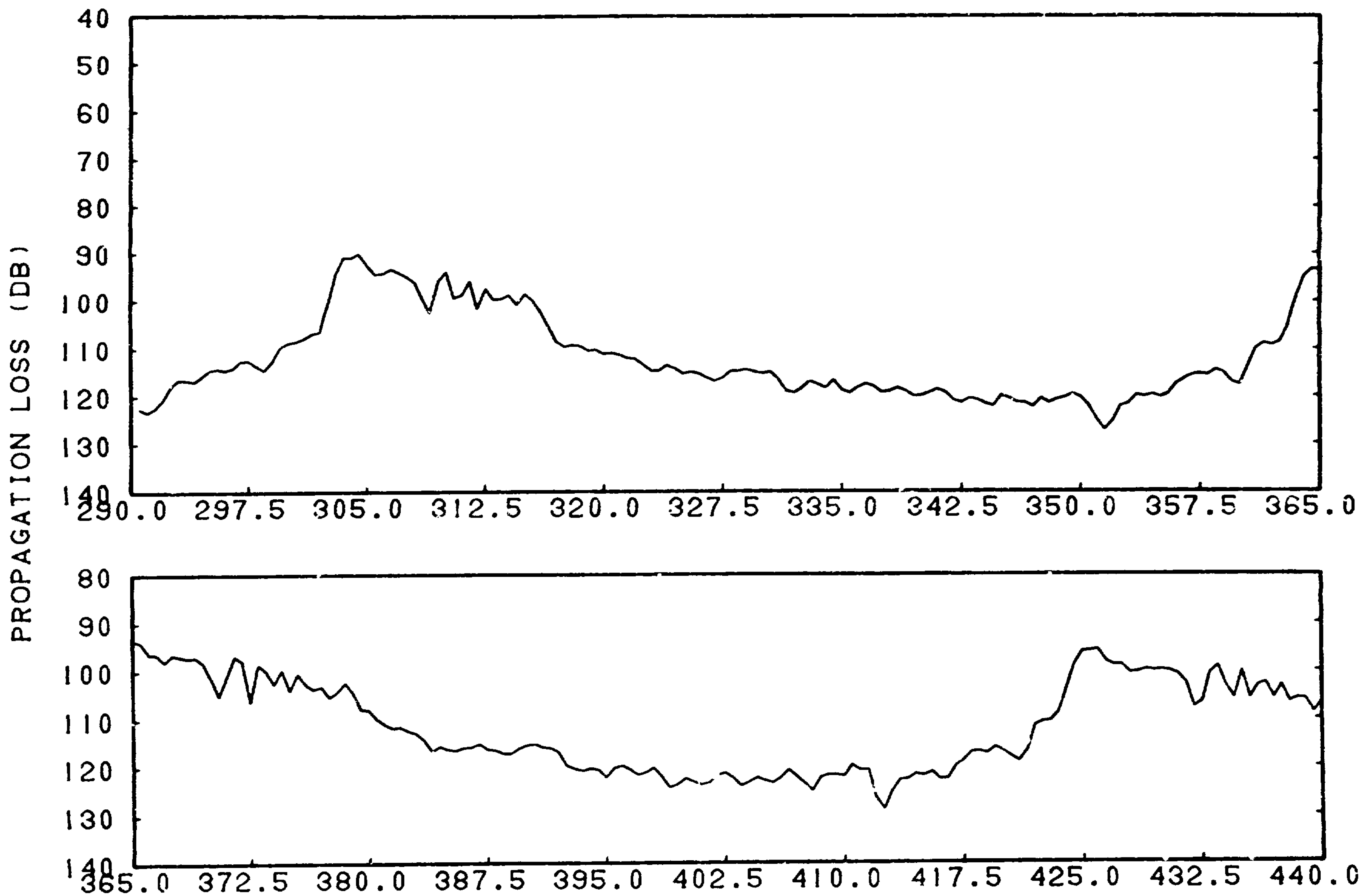
(C) Figure IIIE-44. Smoothed RAYMODE Coherent, Bottom Loss = MGS 7, Run 14S, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 30 Meters, Subtracted from LORAD Data, Run 14S, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 30 Meters



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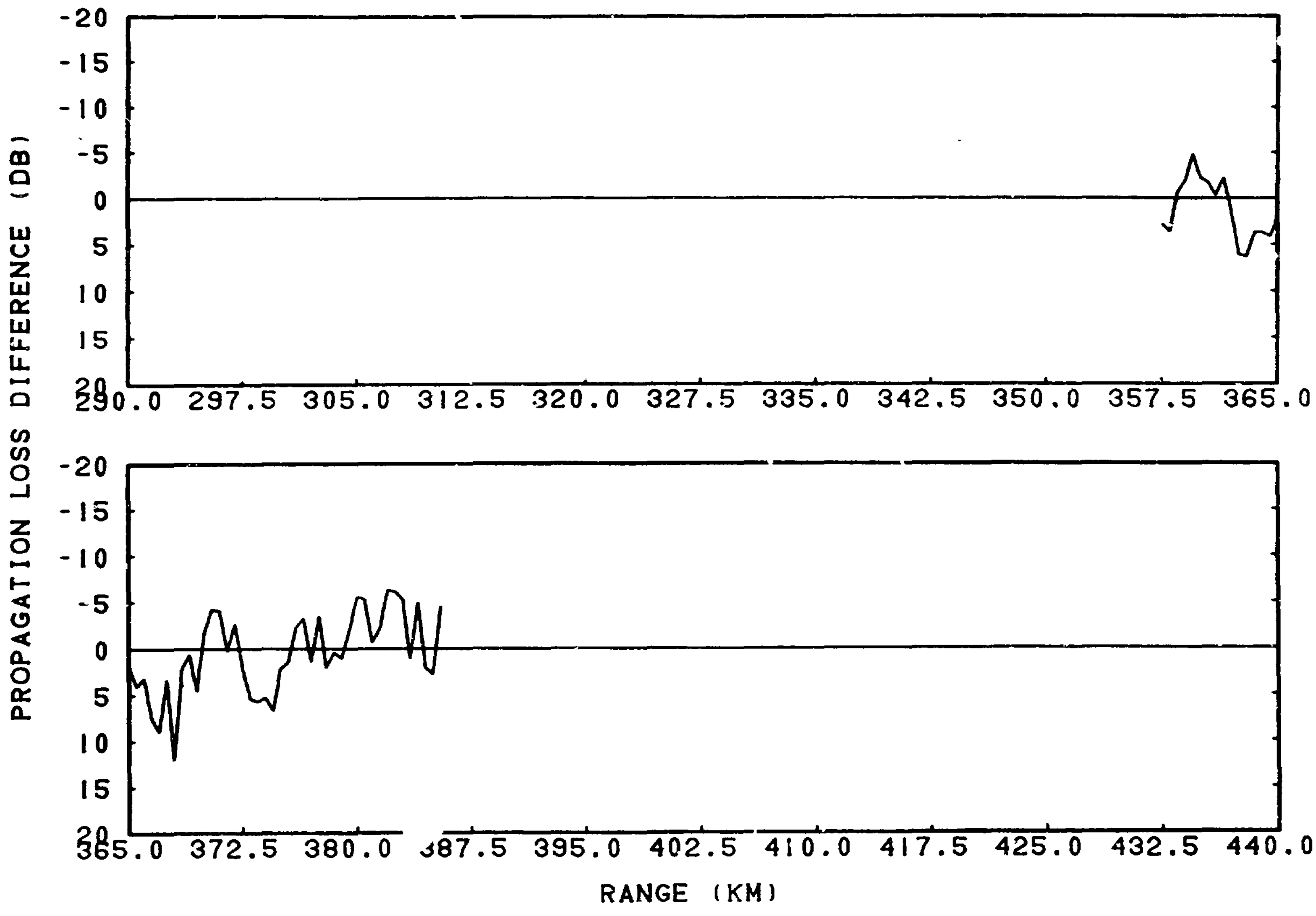
(C) Figure IIIE-45. RAYMODE Incoherent, Bottom Loss = MGS 7, Run 14S, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 30 Meters



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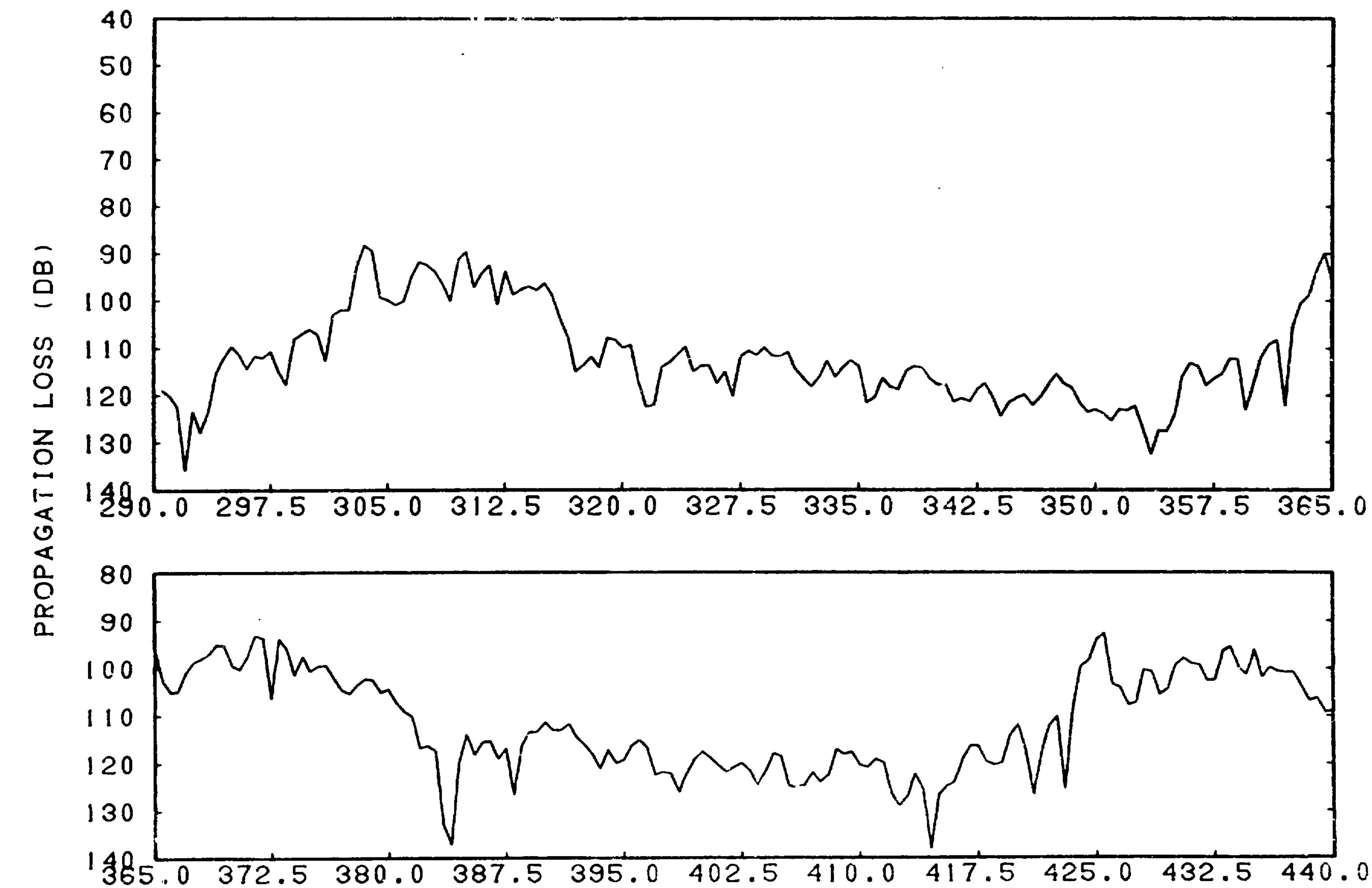
(C) Figure IIIE-46. RAYMODE Incoherent, Bottom Loss = MGS 7, Run 14S, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 30 Meters, Subtracted from LORAD Data, Run 14S, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 30 Meters



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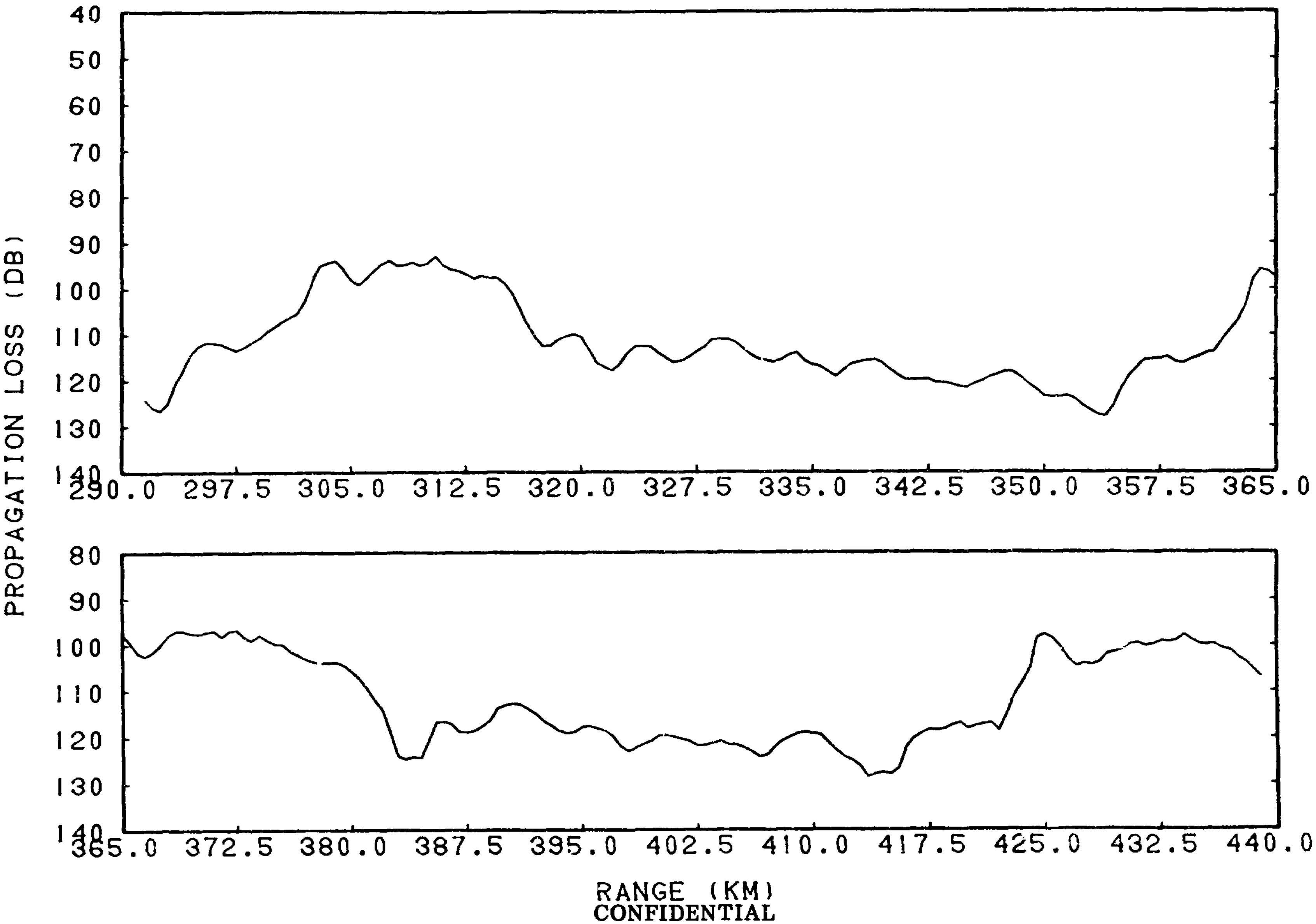
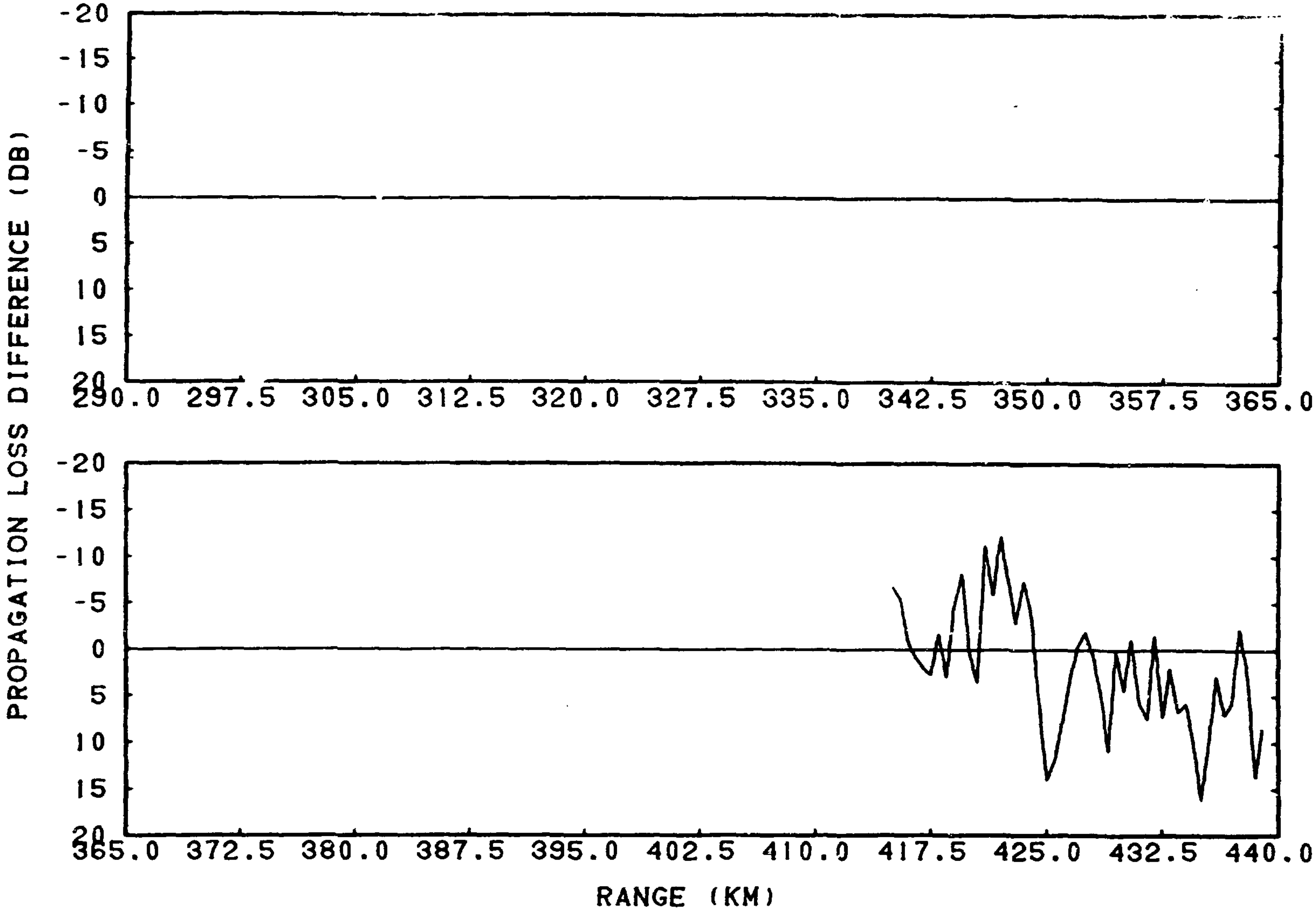
(C) Figure IIIE-47. RAYMODE Coherent, Bottom Loss = MGS 7, Run 16S, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 30 Meters



(C) Figure IIIE-48. RAYMODE Coherent, Bottom Loss = MGS 7, Run 16S, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 30 Meters, Sliding Averages of 5 Points (2.00 Kilometers)



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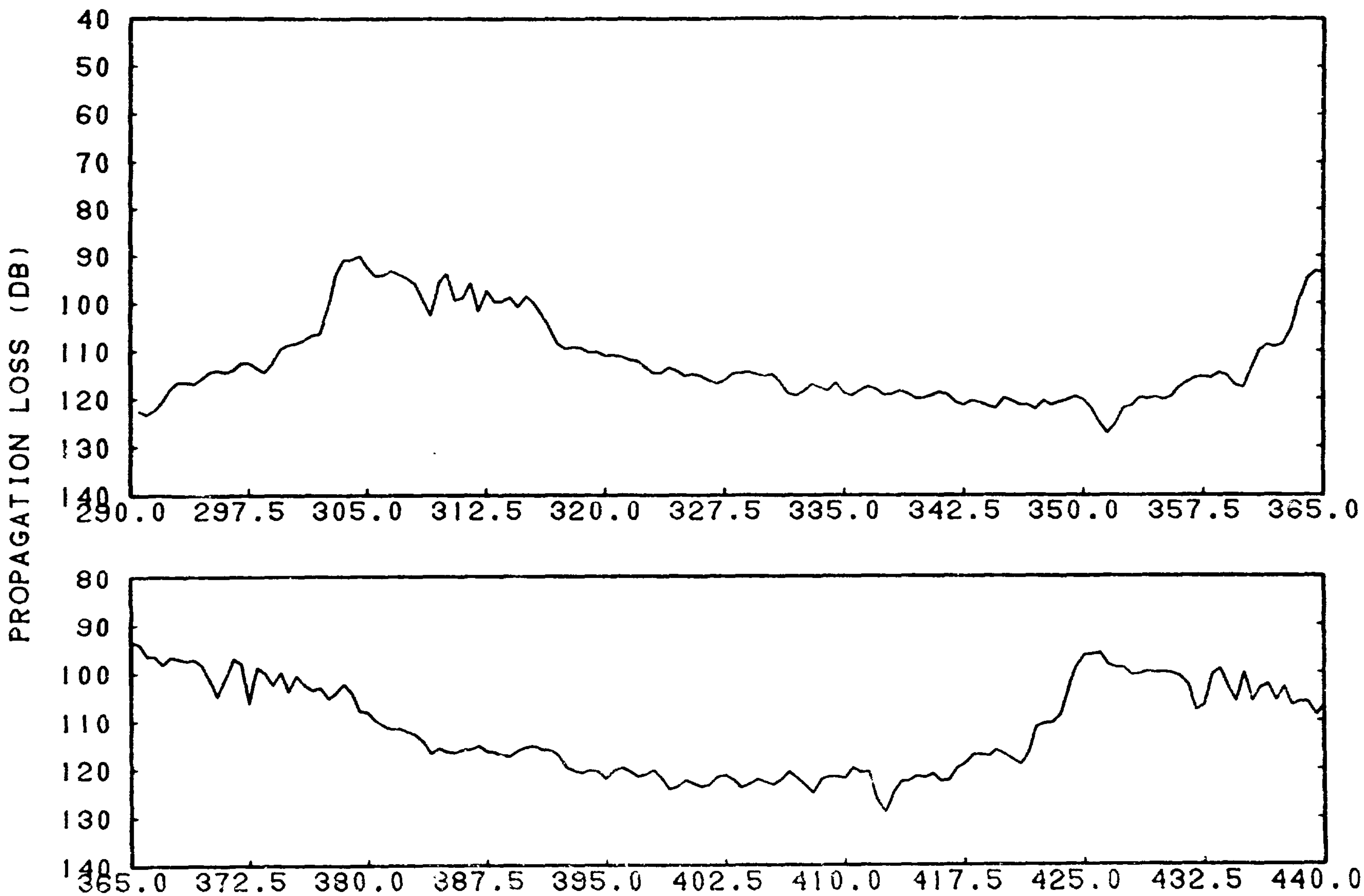
(C) Figure IIIE-49. Smoothed RAYMODE Coherent, Bottom Loss = MGS 7, Run 16S, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 30 Meters, Subtracted from LORAD Data, Run 16S, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 30 Meters



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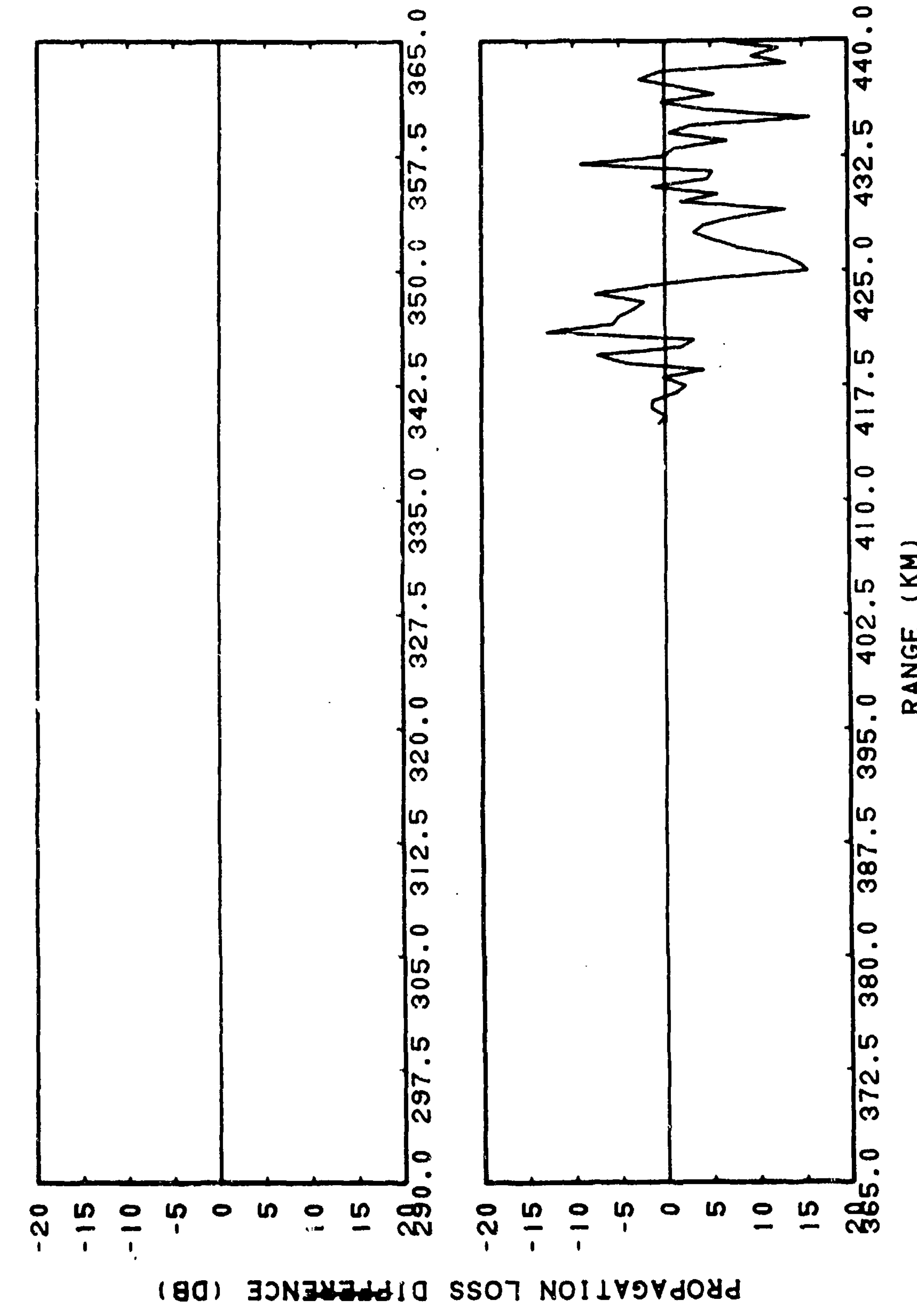
(C) Figure IIIE-50. RAYMODE Incoherent, Bottom Loss = MGS 7, Run 16S, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 30 Meters



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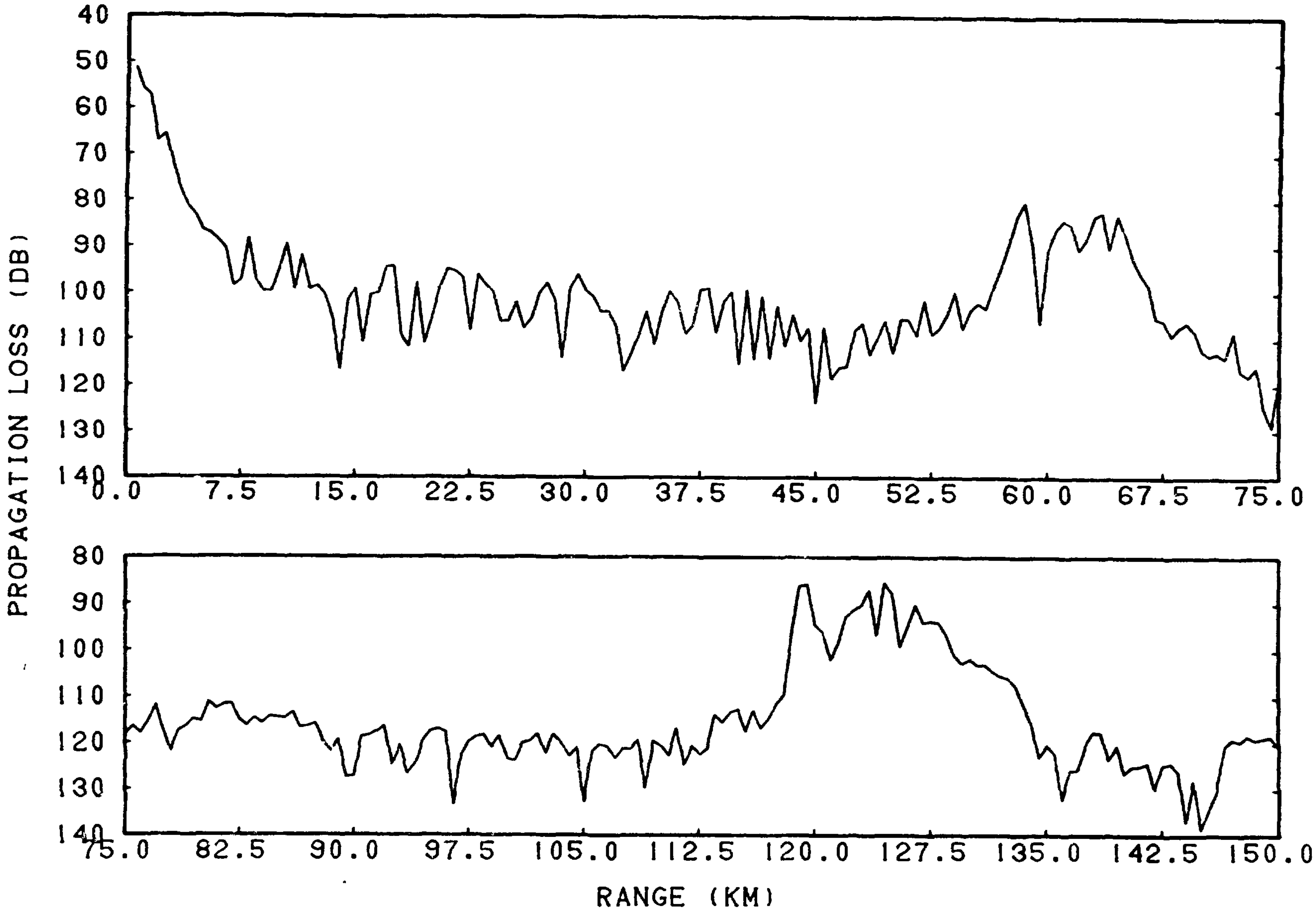
(C) Figure IIIE-51. RAYMODE Incoherent, Bottom Loss = MGS 7, Run 16S, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 30 Meters, Subtracted from LORAD Data, Run 16S, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 30 Meters



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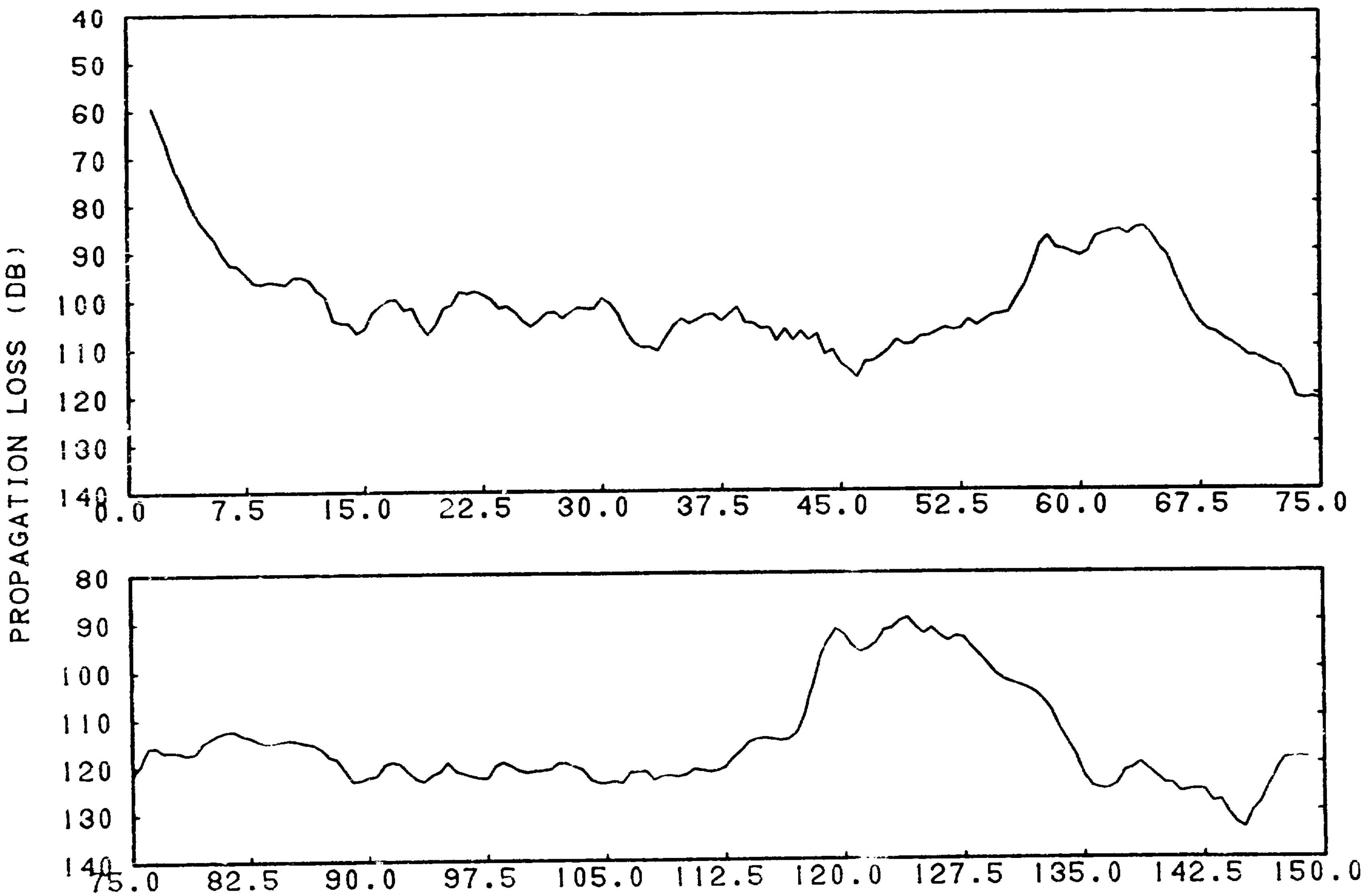
(C) Figure IIIE-52. RAYMODE Coherent, Bottom Loss = MGS 7, Run 3D, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 305 Meters



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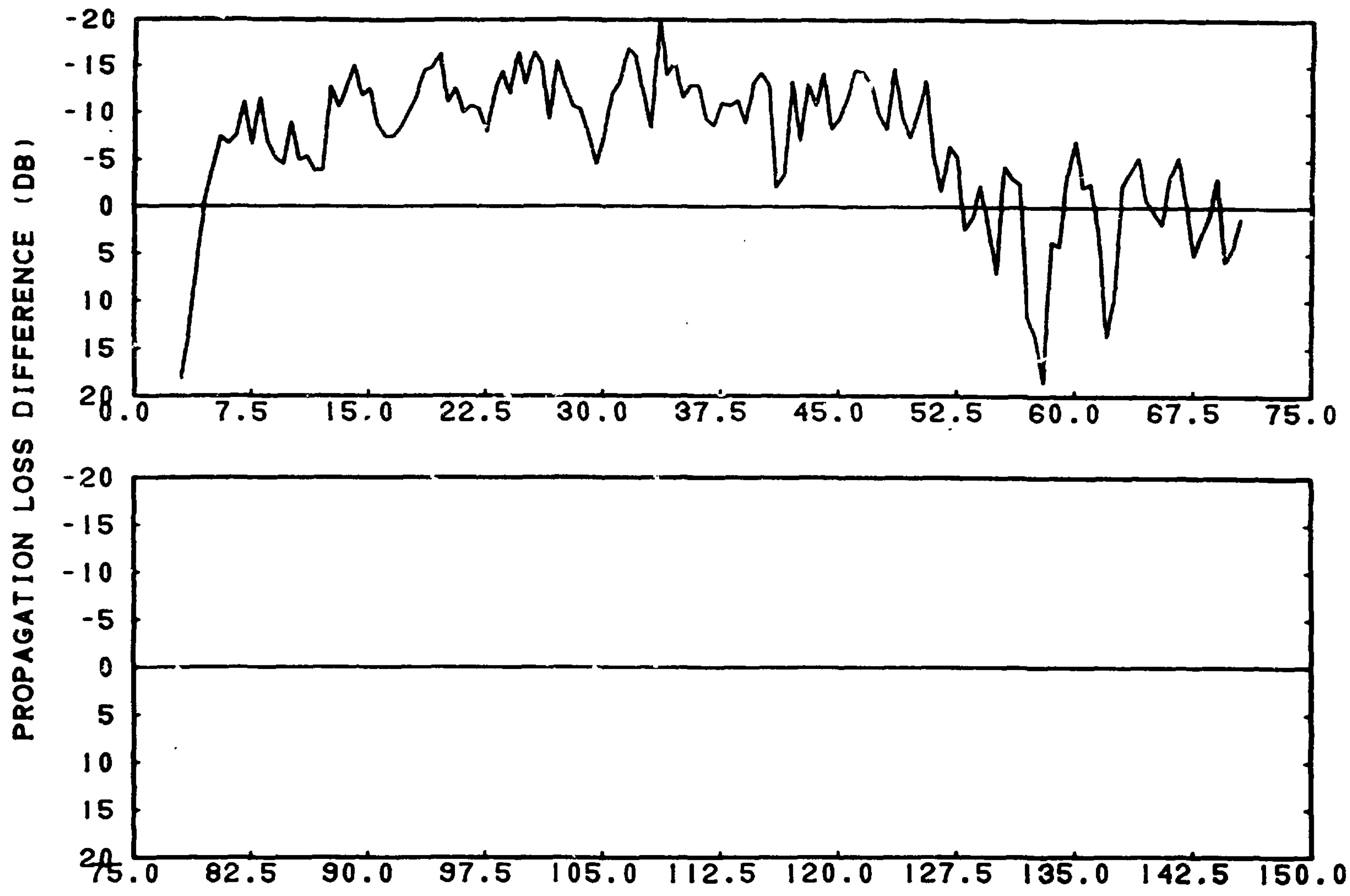
(C) Figure IIIE-53. RAYMODE Coherent, Bottom Loss = MGS 7, Run 3D, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 305 Meters, Sliding Averages of 5 Points (2.00 Kilometers)



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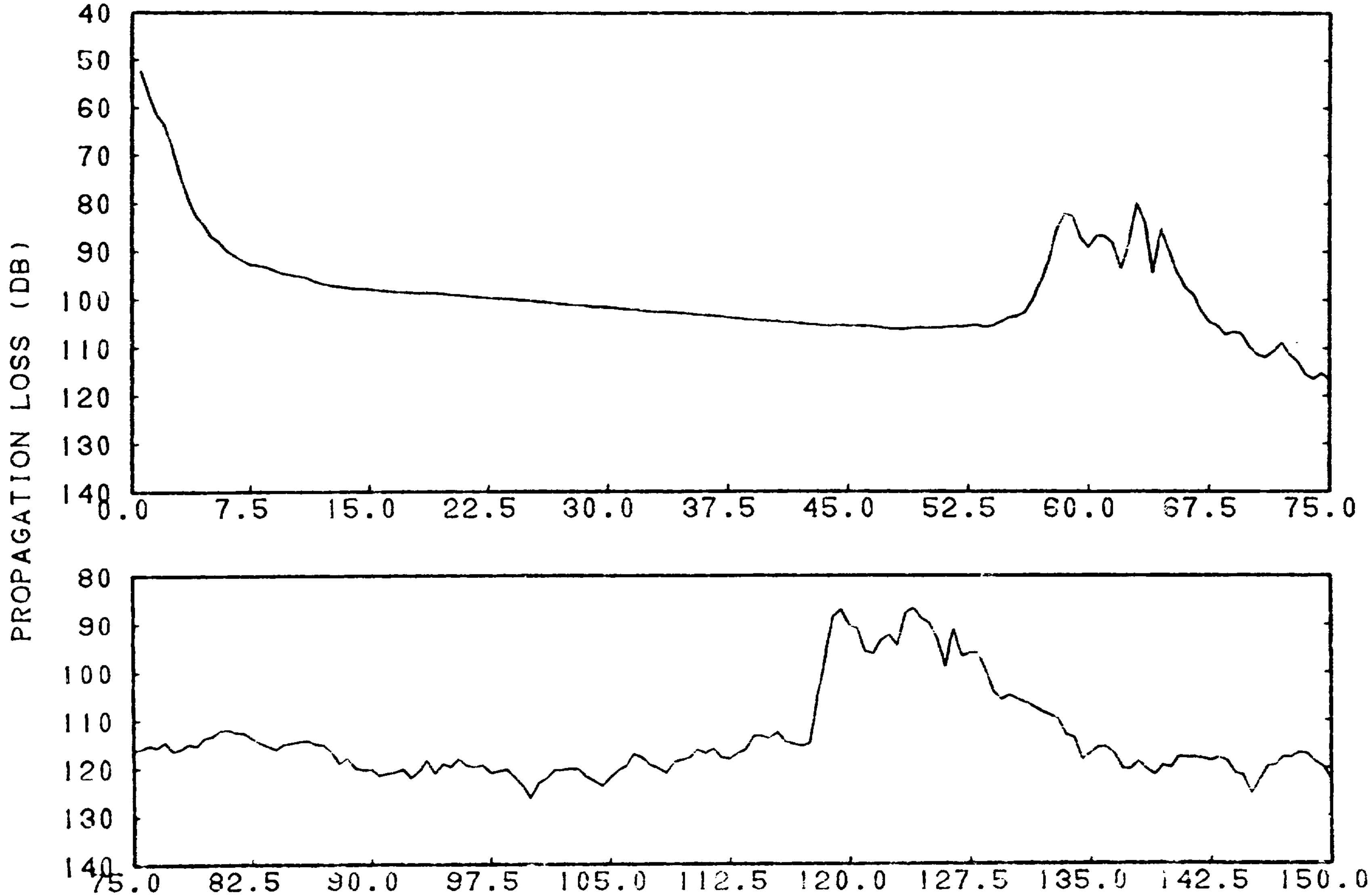
(C) Figure IIIE-54. Smoothed RAYMODE Coherent, Bottom Loss = MGS 7, Run 3D, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 305 Meters, Subtracted from LORAD Data, Run 3D, Frequency = 0.53 Kilohertz Source Depth = 15 Meters, Receiver Depth = 305 Meters



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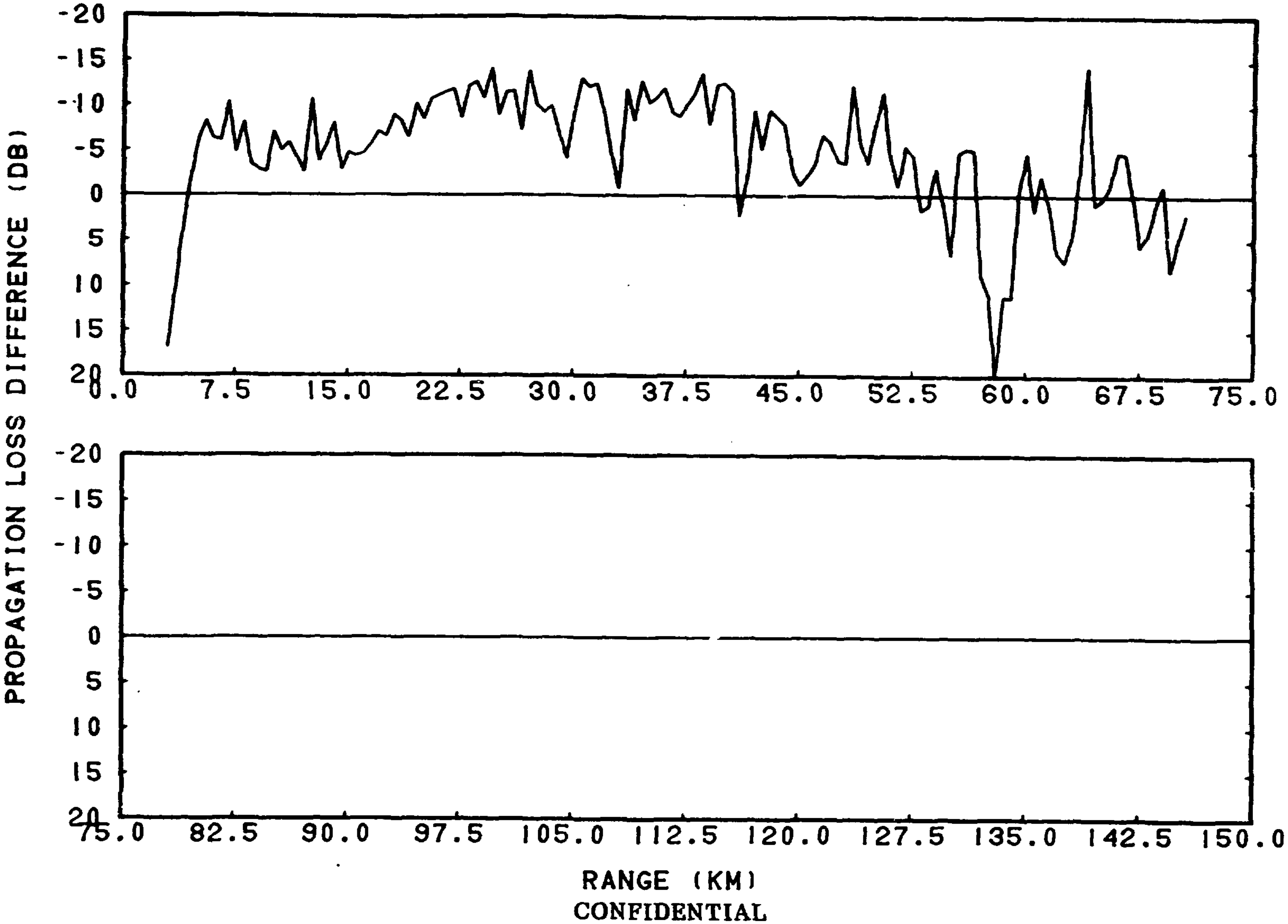
(C) Figure IIIE-55. RAYMODE Incoherent, Bottom Loss = MGS 7, Run 3D, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 305 Meters



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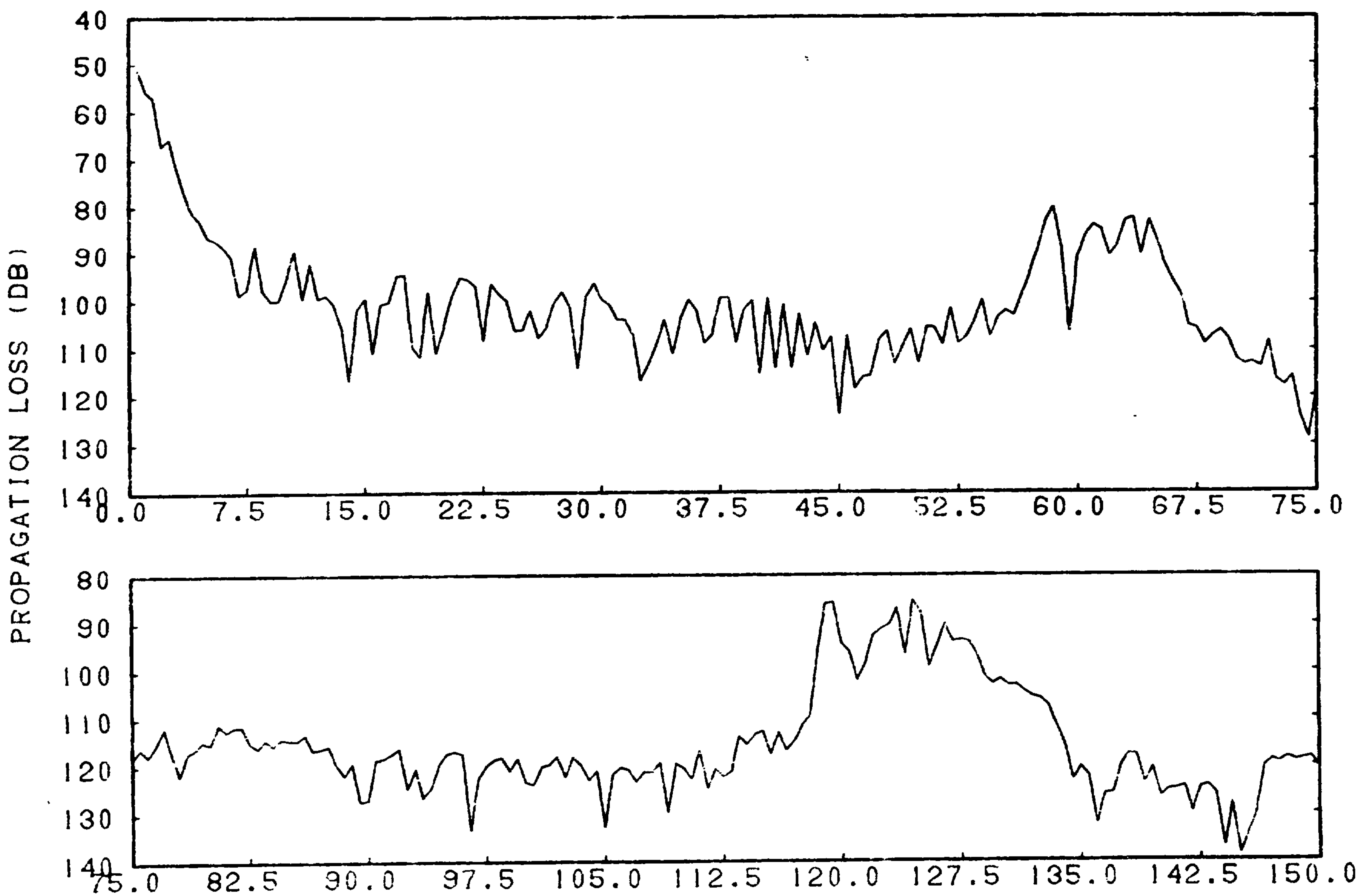
(C) Figure IIIE-56. RAYMODE Incoherent, Bottom Loss = MGS 7, Run 3D, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 305 Meters, Subtracted from LORAD Data, Run 3D, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 305 Meters



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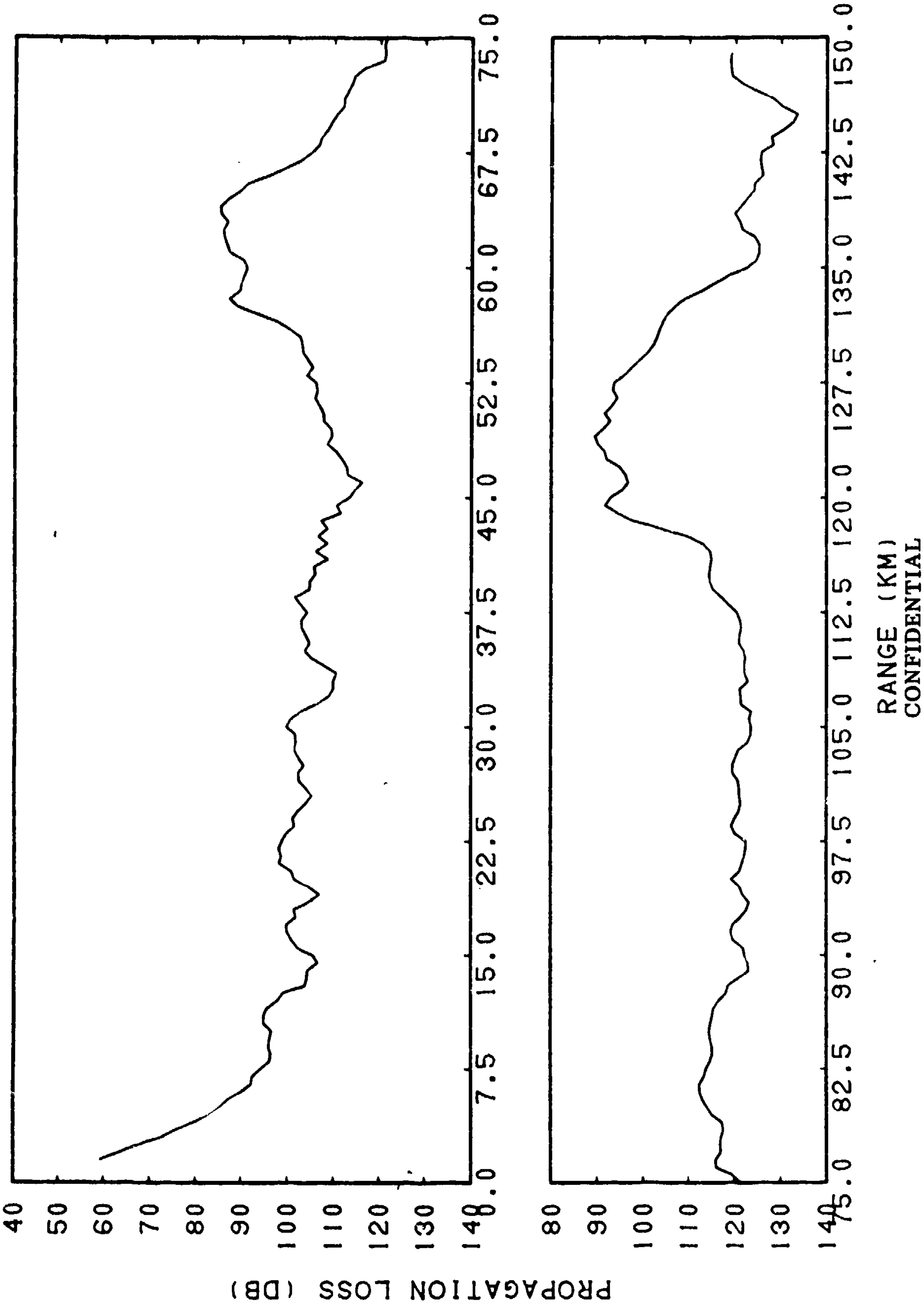
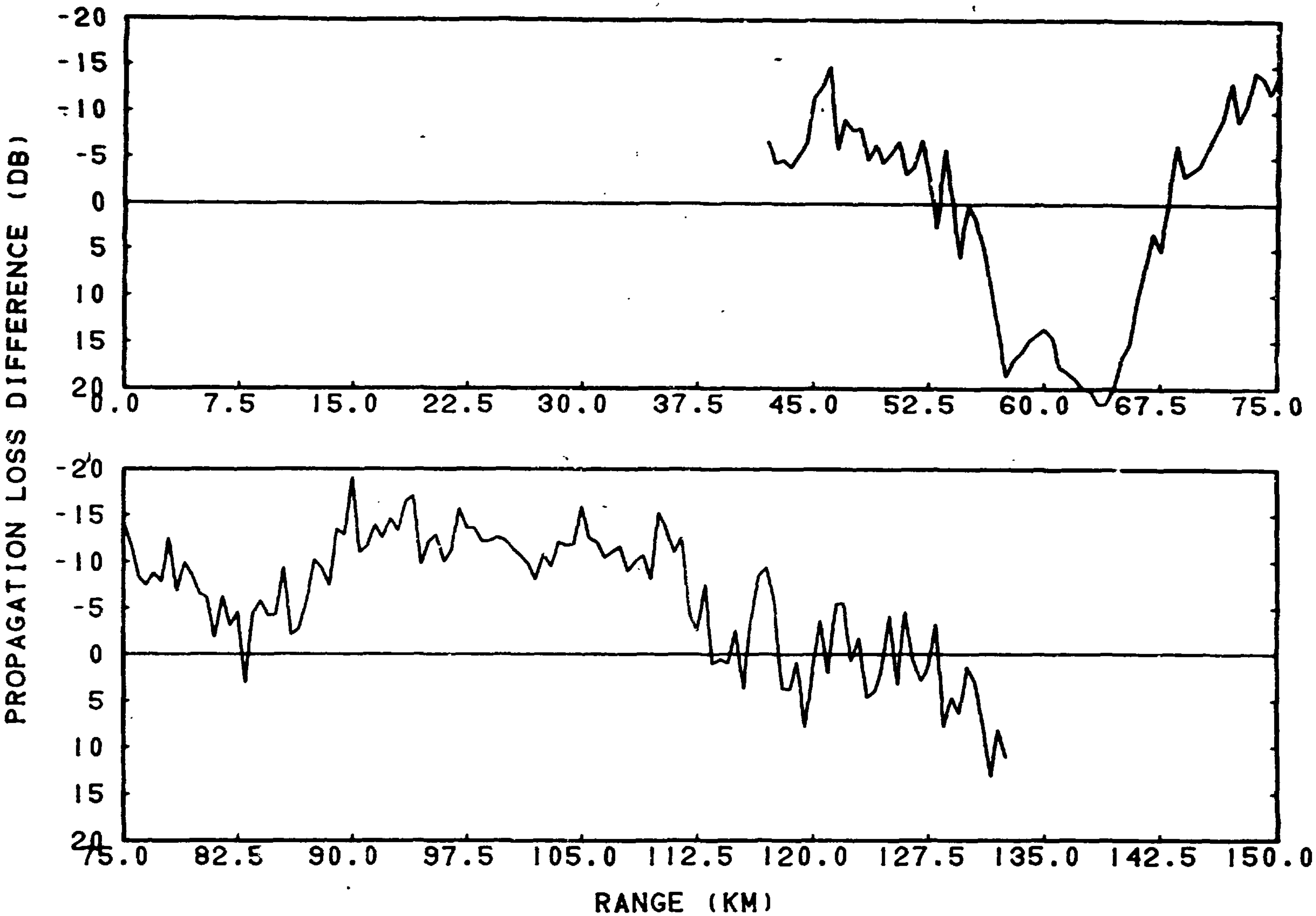
(C) Figure IIIE-57. RAYMODE Coherent, Bottom Loss = MGS 7, Run 6D, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 305 Meters



(C) Figure IIIE-58. RAYMODE Coherent, Bottom Loss = MGS 7, Run 6D, Frequency = 0 53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 305 Meters, Sliding Averages of 5 Points (2.00 Kilometers)



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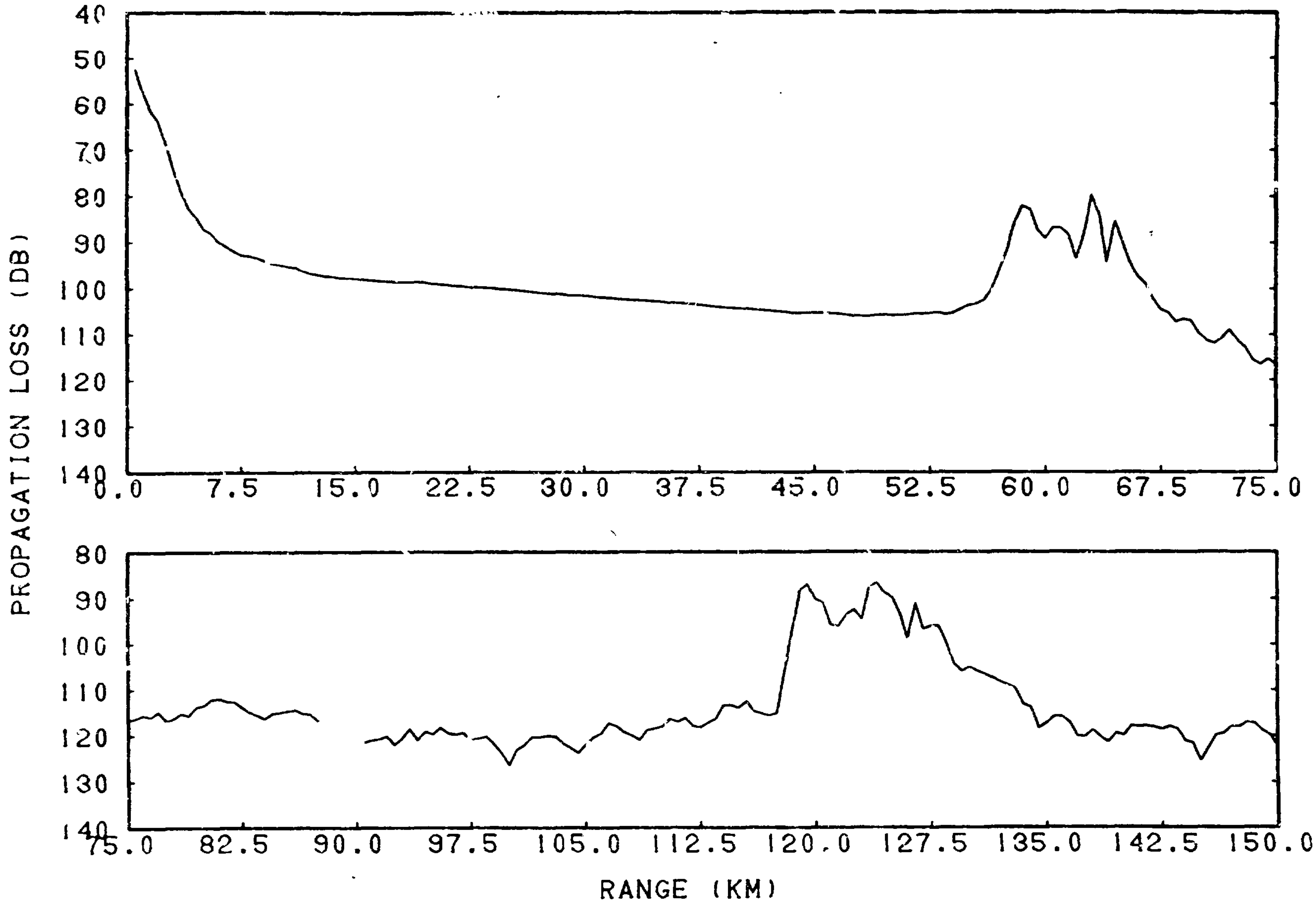
(C) Figure IIIE-59. Smoothed RAYMODE Coherent, Bottom Loss = MGS 7, Run 6D, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 305 Meters, Subtracted from LORAD Data, Run 6D, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 305 Meters



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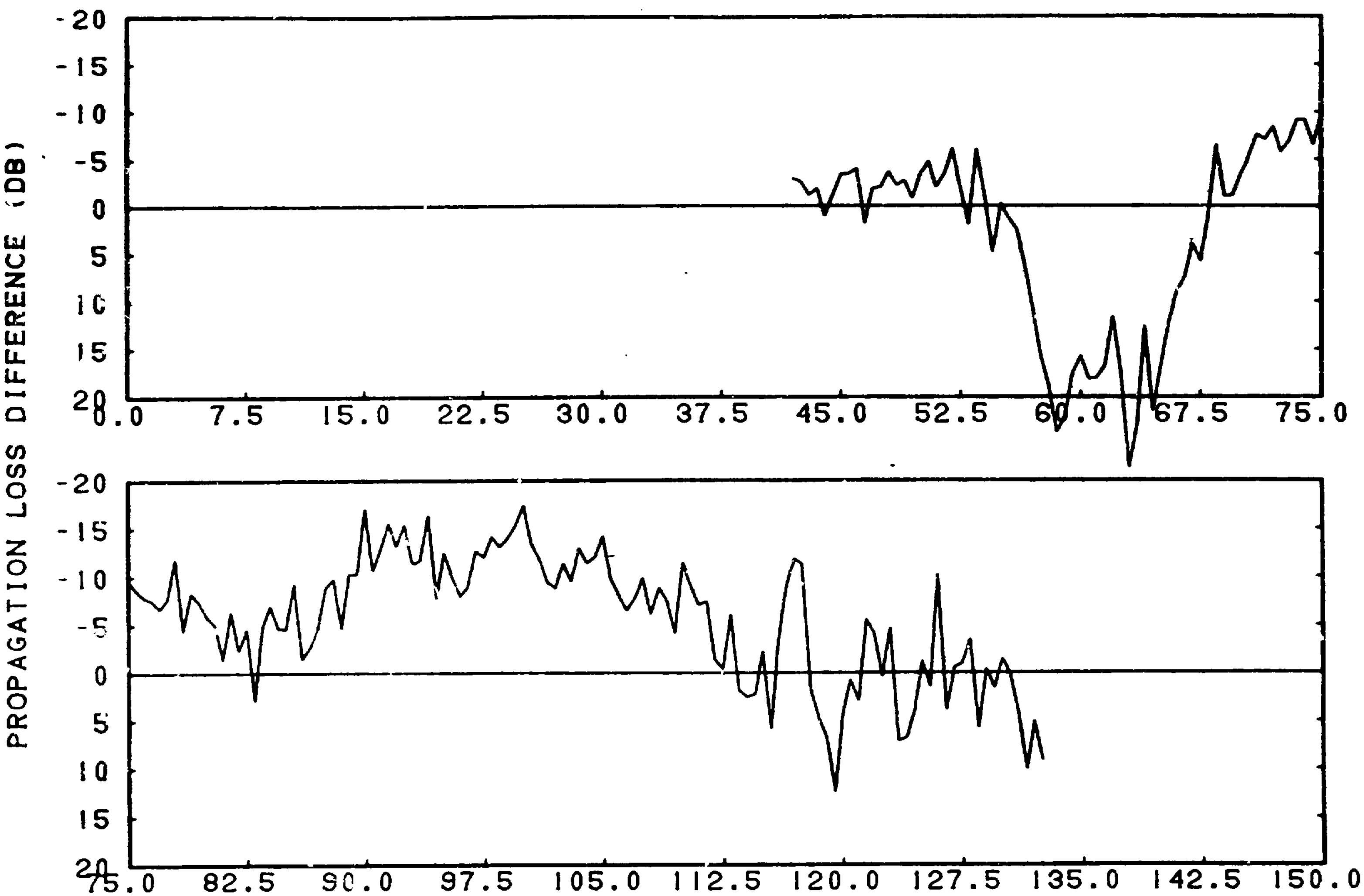
(C) Figure IIIE-60. RAYMODE Incoherent, Bottom Loss = MGS 7, Run 6D, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 305 Meters



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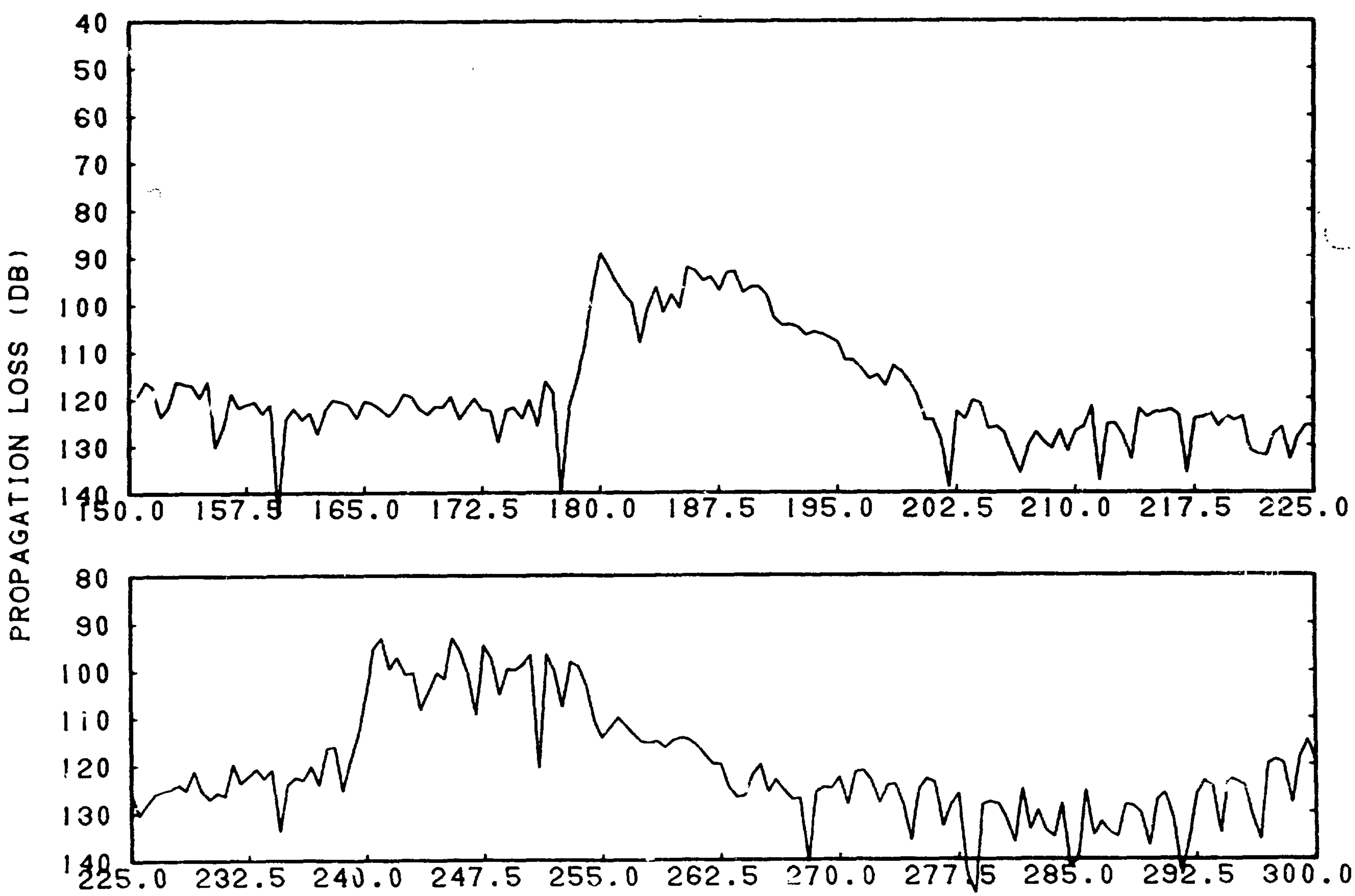
(C) Figure IIIE-61. RAYMODE Incoherent, Bottom Loss = MGS 7, Run 6D, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 305 Meters, Subtracted from LORAD Data, Run 6D, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 305 Meters



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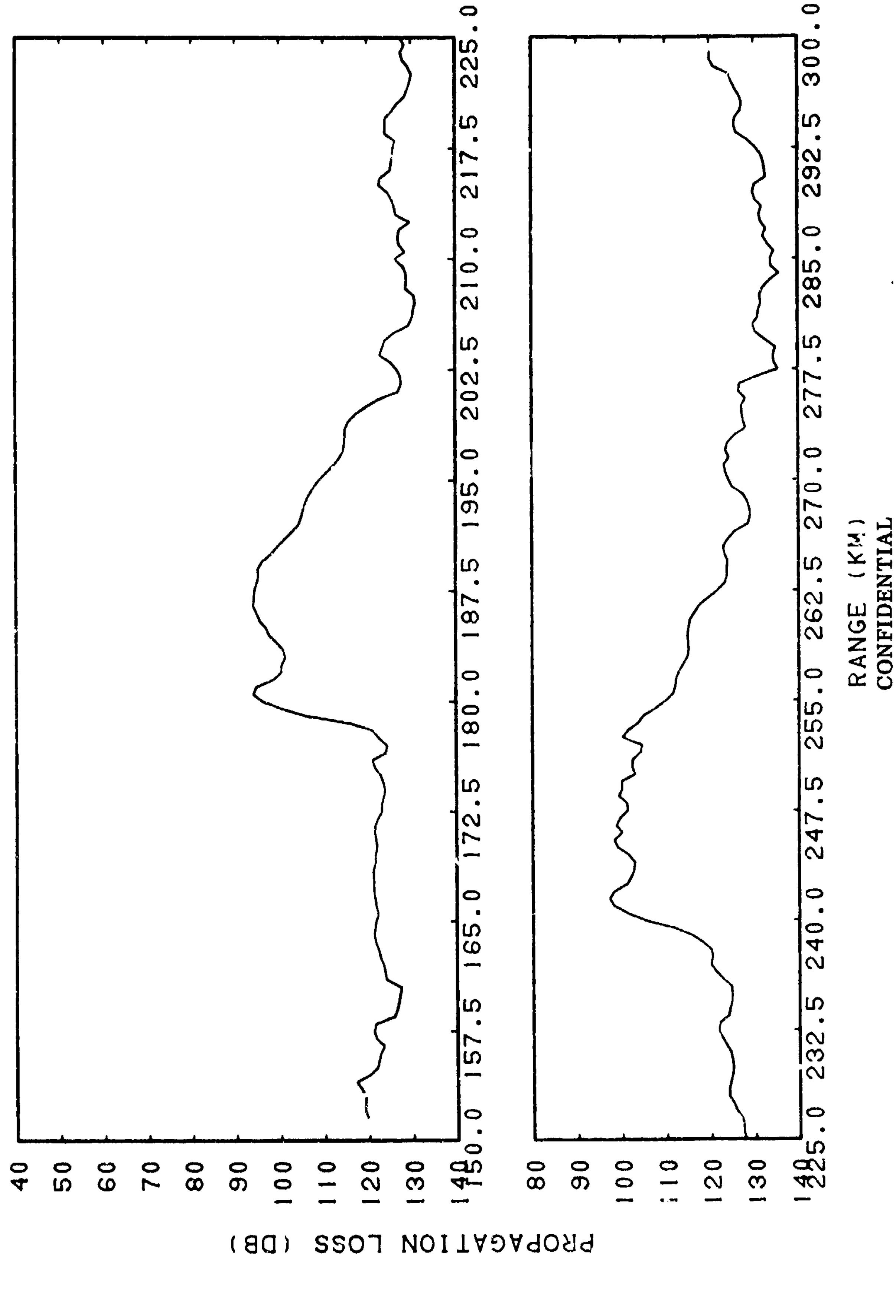
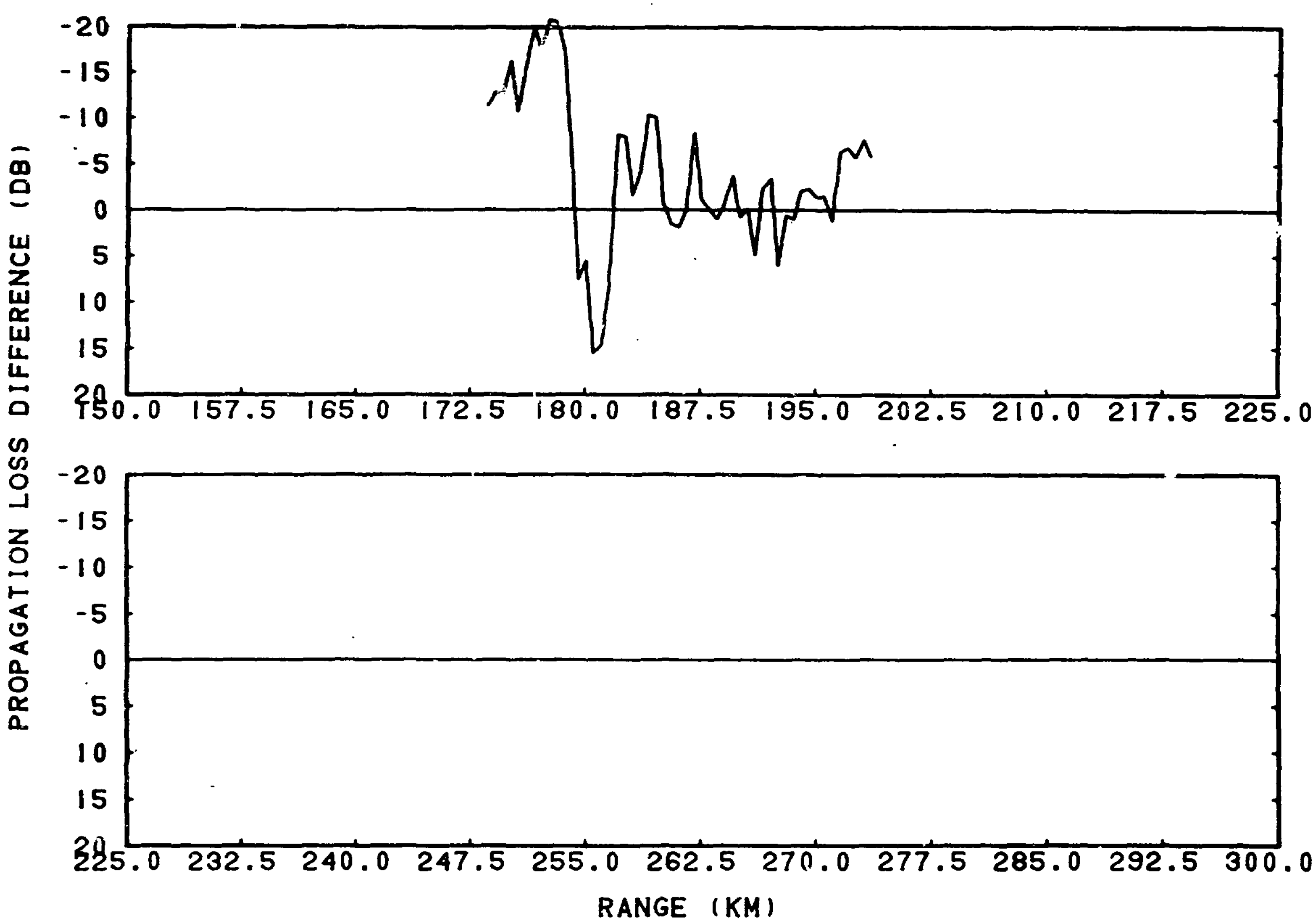
(C) Figure IIIE-62. RAYMODE Coherent, Bottom Loss = MGS 7, Run 8D, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 305 Meters



(C) Figure IIIE-63. RAYMODE Coherent, Bottom Loss = MGS 7, Run 8D, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 305 Meters, Sliding Averages of 5 Points (2.00 Kilometers)



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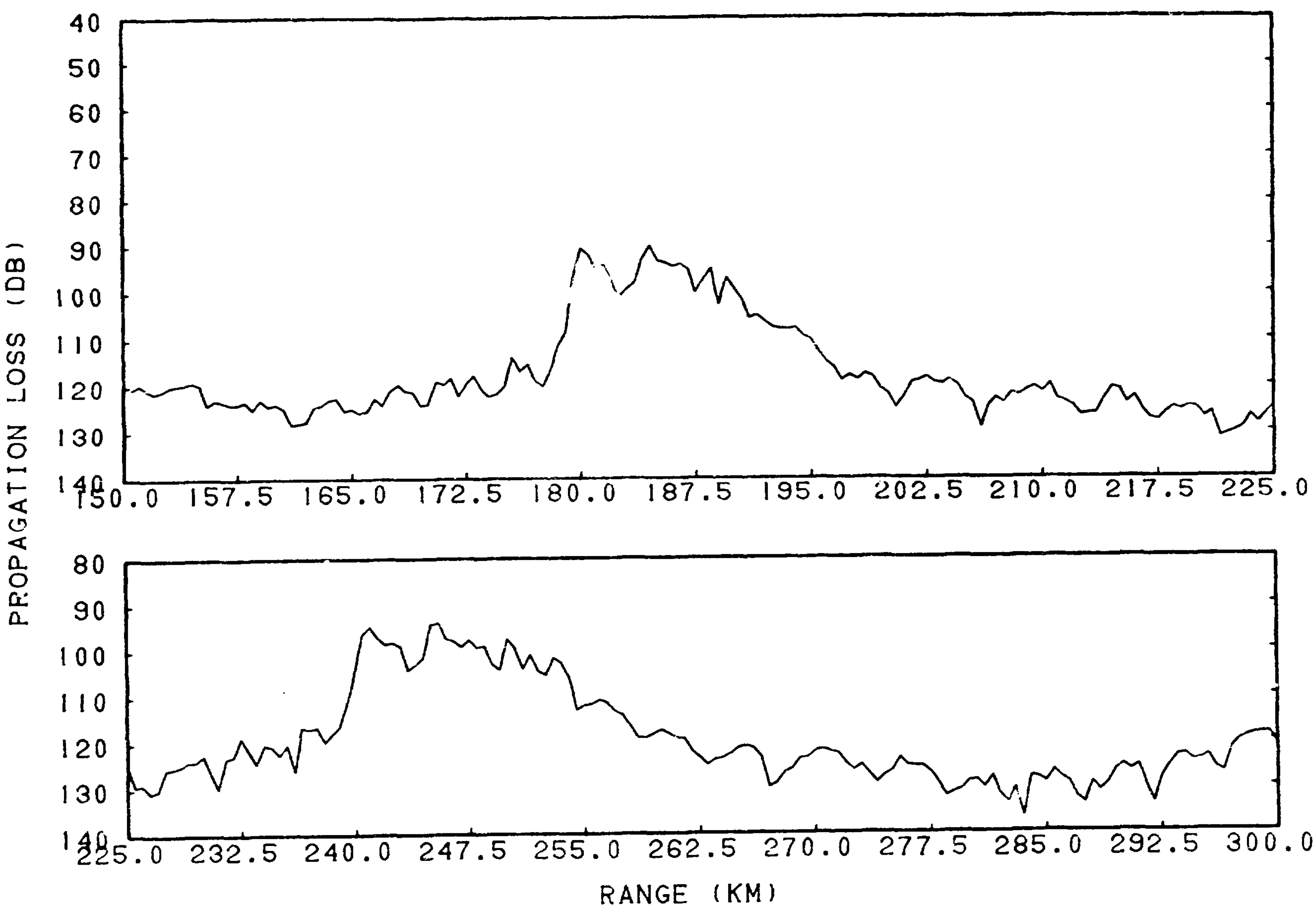
(C) Figure IIIE-64. Smoothed RAYMODE Coherent, Bottom Loss = MGS 7, Run 8D, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 305 Meters, Subtracted from LORAD Data, Run 8D, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 305 Meters



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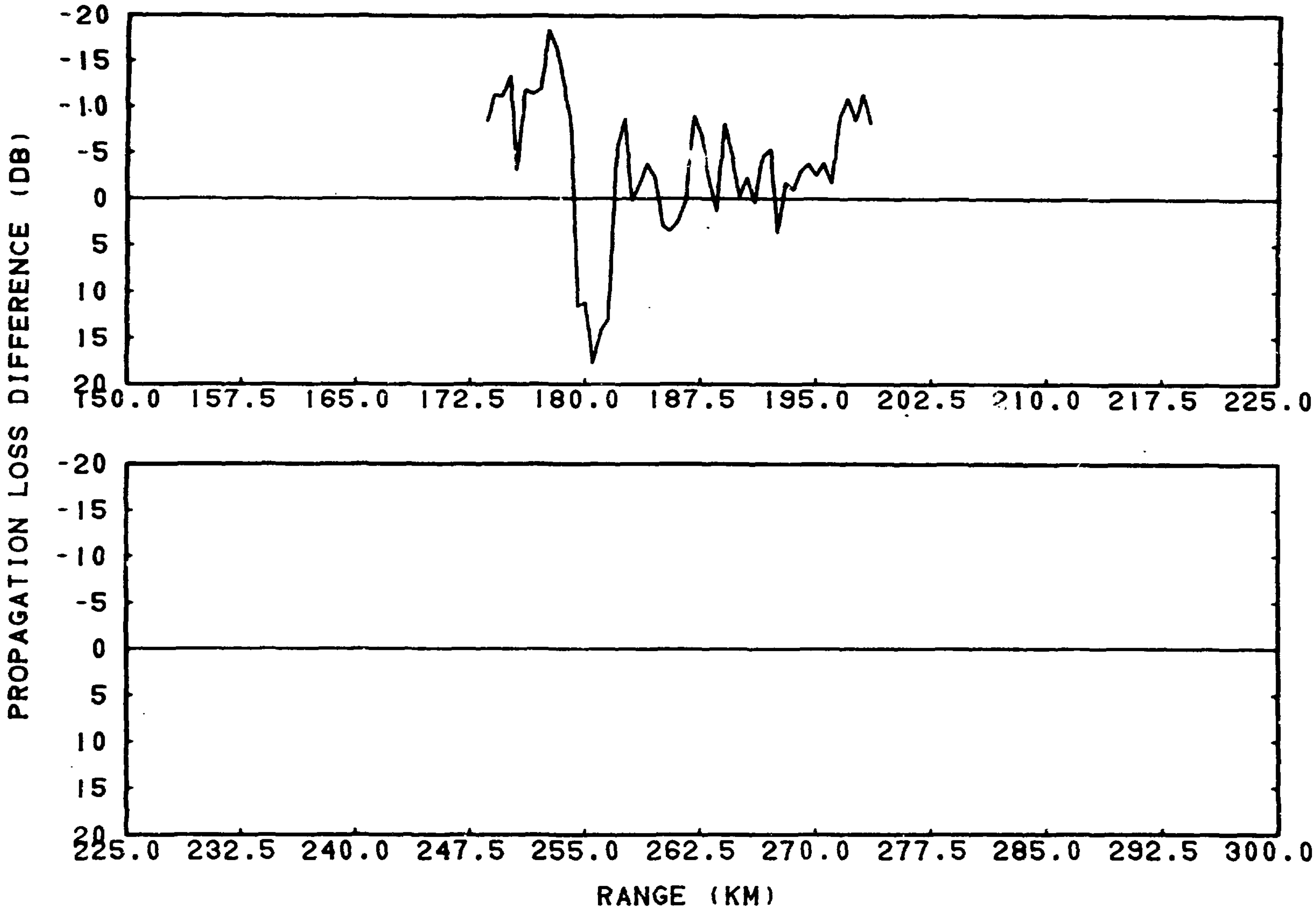
(C) Figure IIIE-65. RAYMODE Incoherent, Bottom Loss = MGS 7, Run 8D, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 305 Meters



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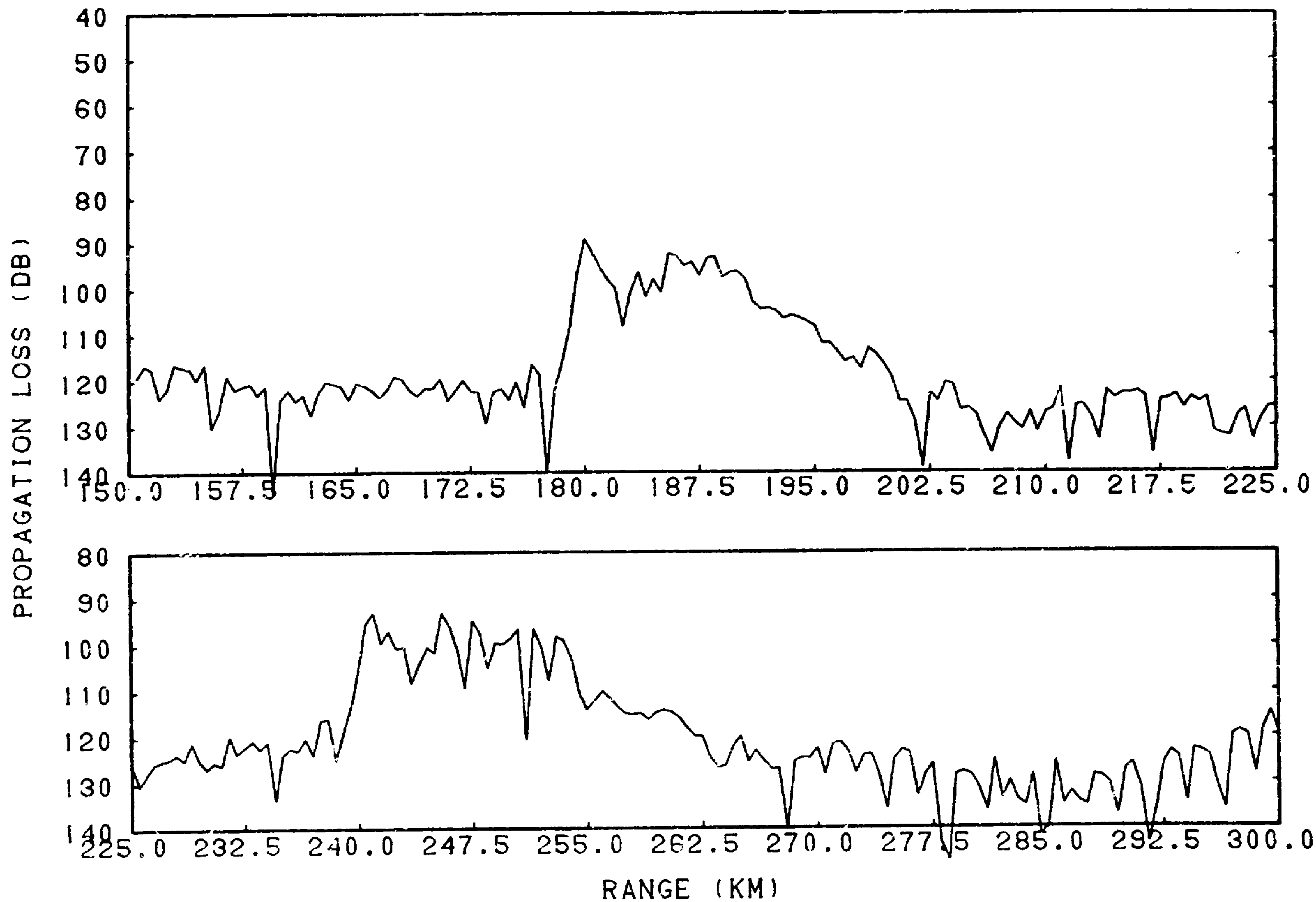
(C) Figure IIIE-66. RAYMODE Incoherent, Bottom Loss = MGS 7, Run 8D, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 305 Meters, Subtracted from LORAD Data, Run 8D, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 305 Meters



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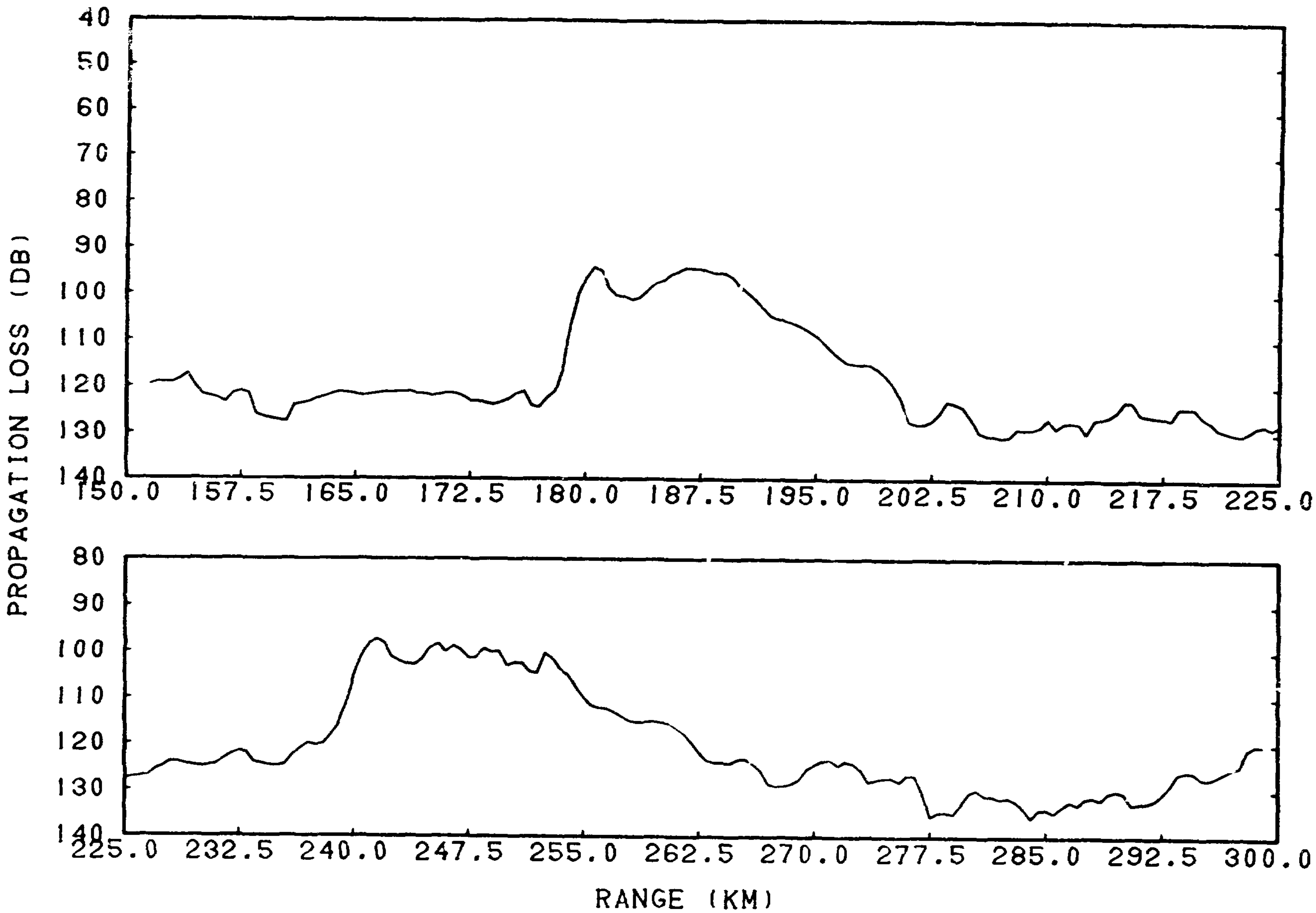
(C) Figure IIIE-67. RAYMODE Coherent, Bottom Loss = MGS 7, Run 10D, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 305 Meters



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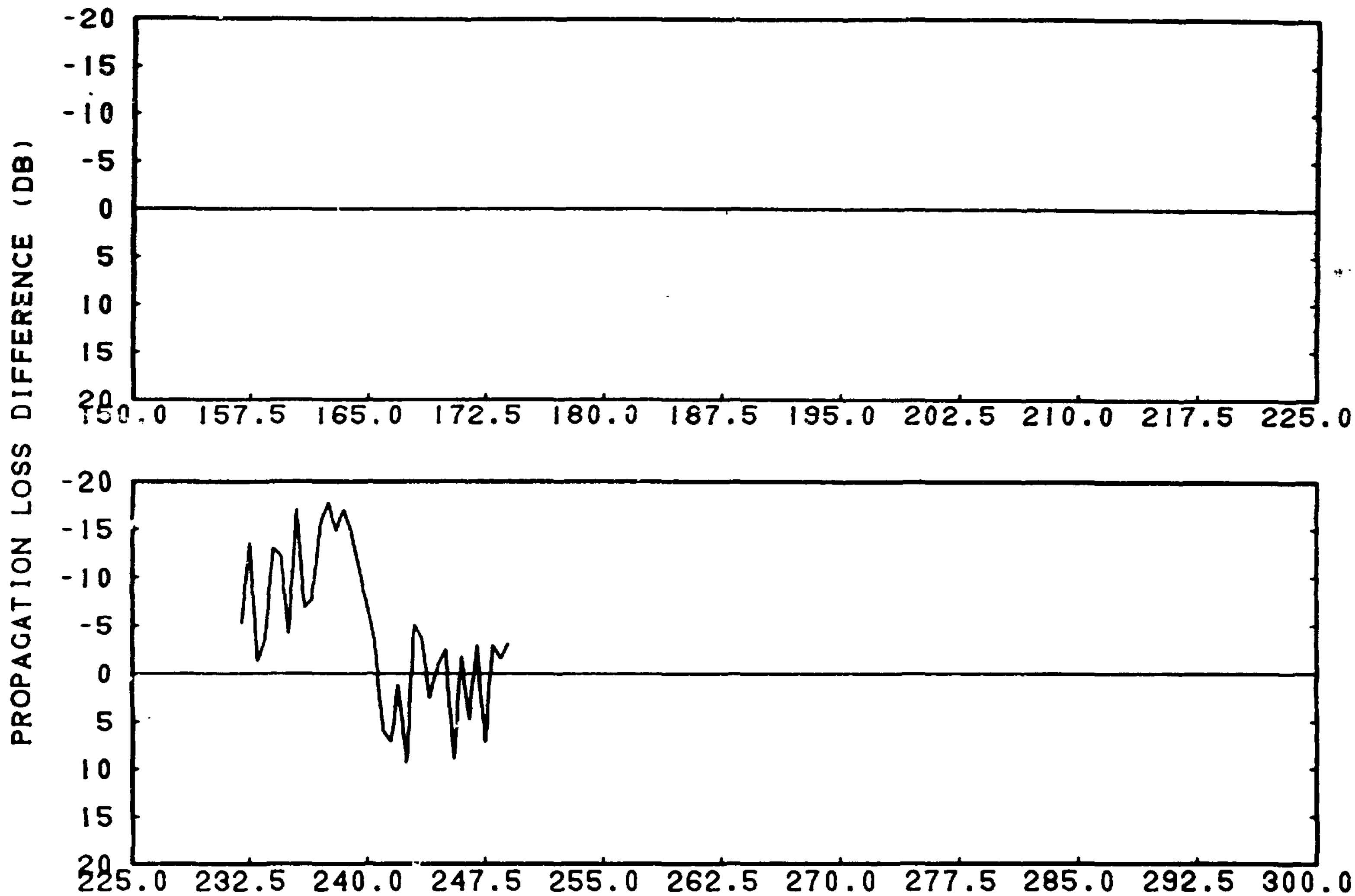
(C) Figure IIIE-66 RAYMODE Coherent, Bottom Loss = MGS 7, Run 10D, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 305 Meters, Sliding Averages of 5 Points (2.00 Kilometers)



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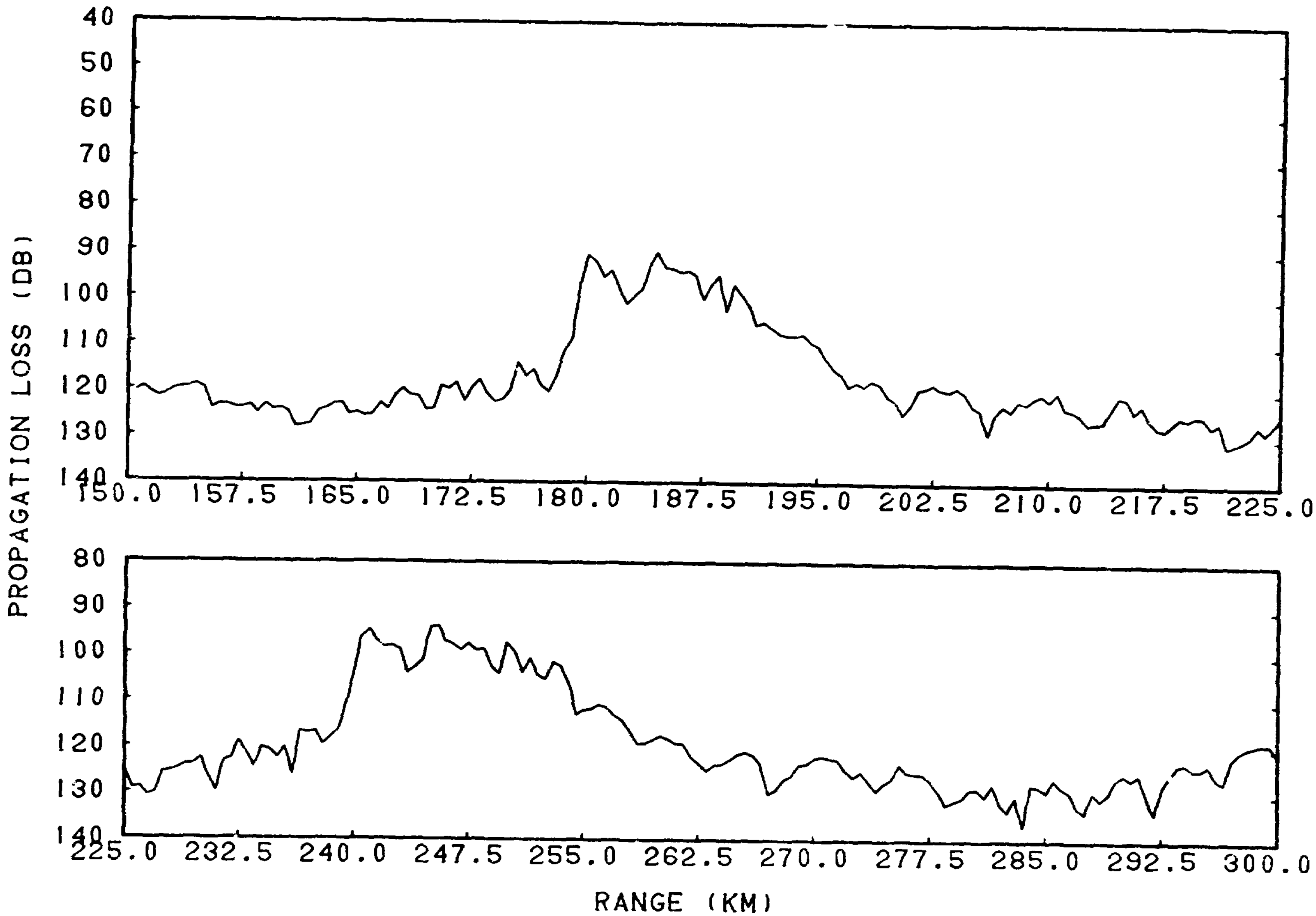
(C) Figure IIIE-69. Smoothed RAYMODE Coherent, Bottom Loss = MGS 7, Run 10D, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 305 Meters, Subtracted from LORAD Data, Run 10D, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 305 Meters



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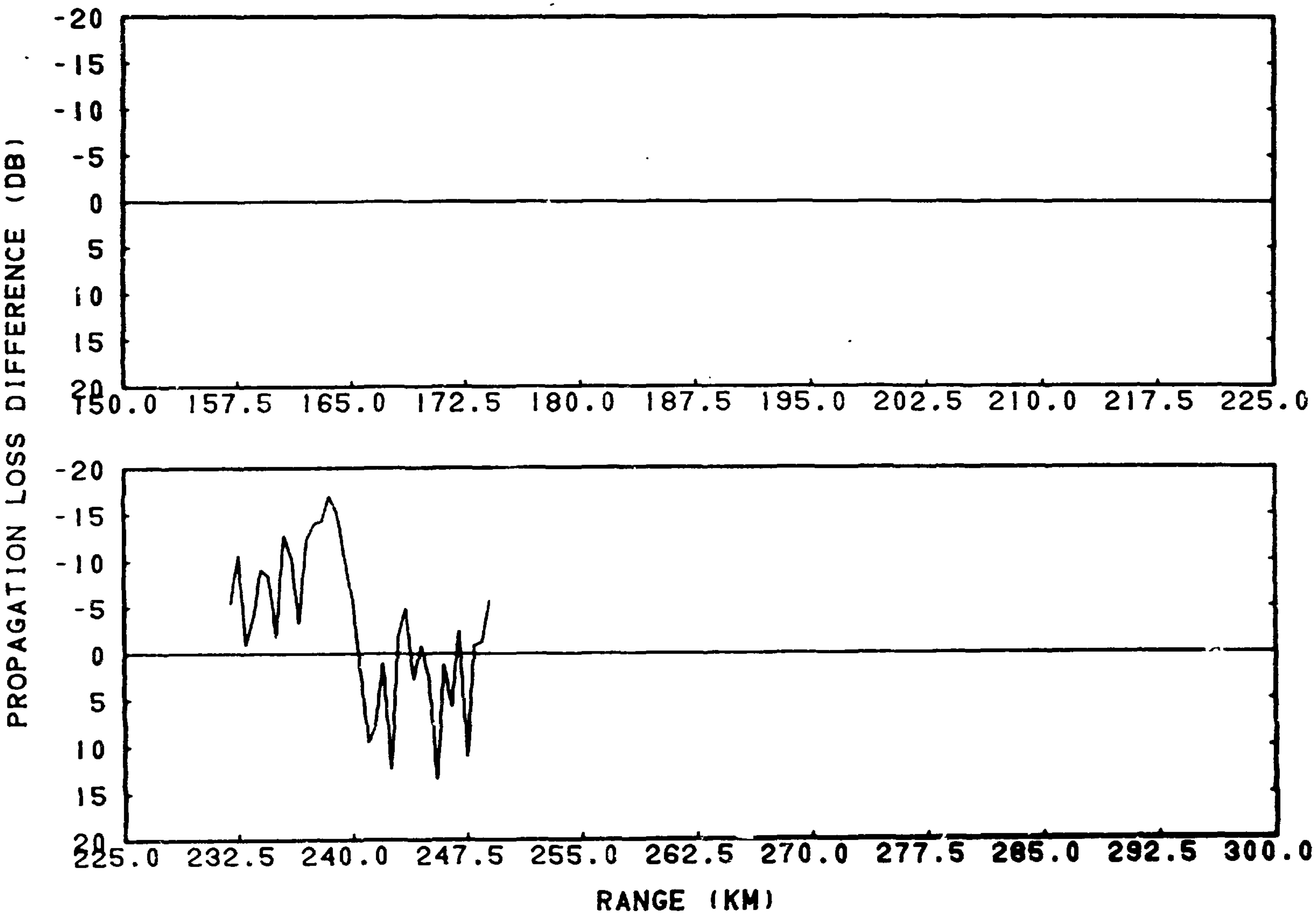
(C) Figure IIIE-70. RAYMODE Incoherent, Bottom Loss = MGS 7, Run 10D, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 305 Meters



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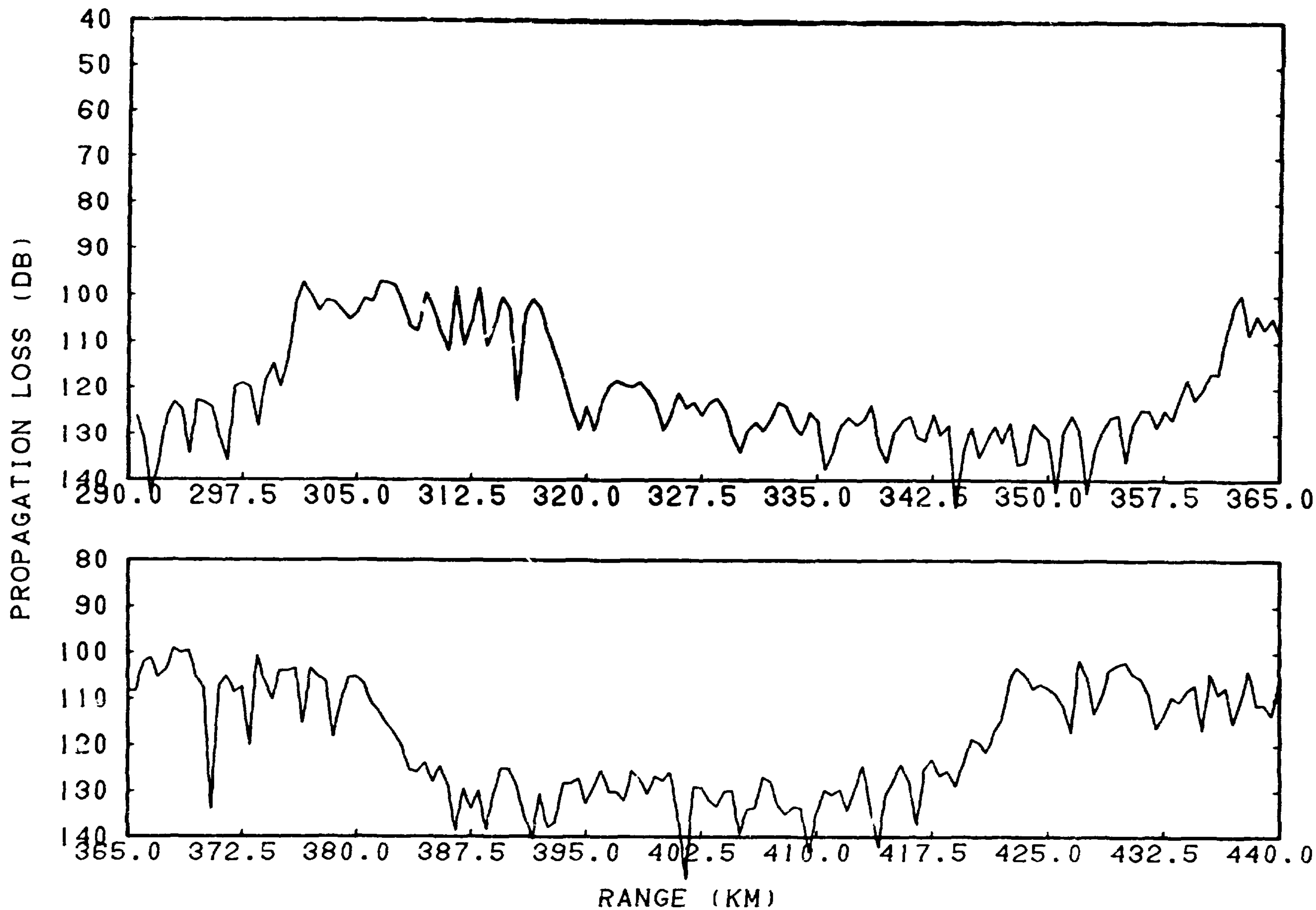
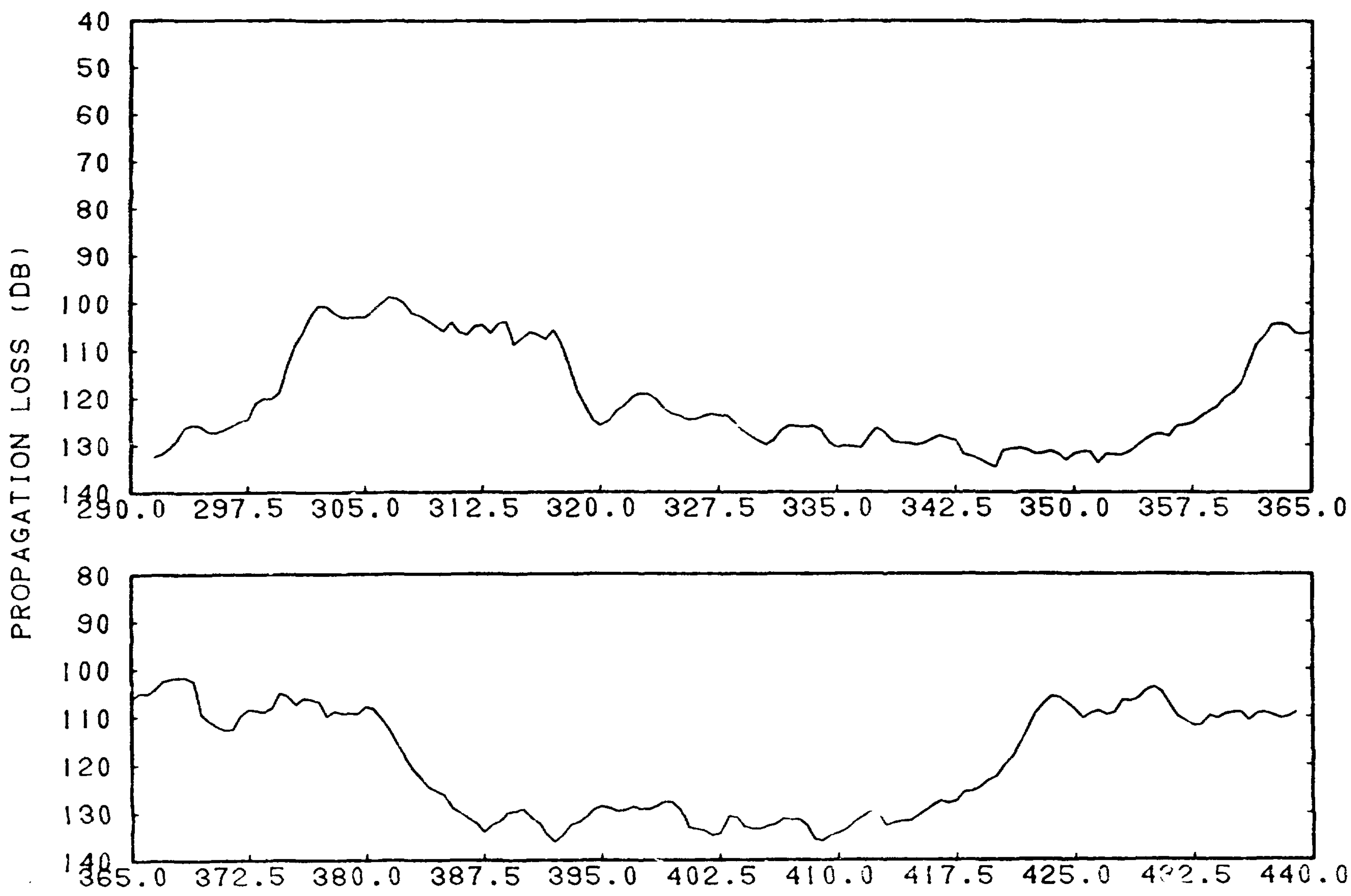
(C) Figure IIIE-71. RAYMODE Incoherent. Bottom Loss = MGS 7, Run 10D, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 305 Meters, Subtracted from LORAD Data, Run 10D, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 305 Meters



CONFIDENTIAL

(C) Figure IIIE-72. RAYMODE Coherent, Bottom Loss = MGS 7, Run 12D, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 305 Meters



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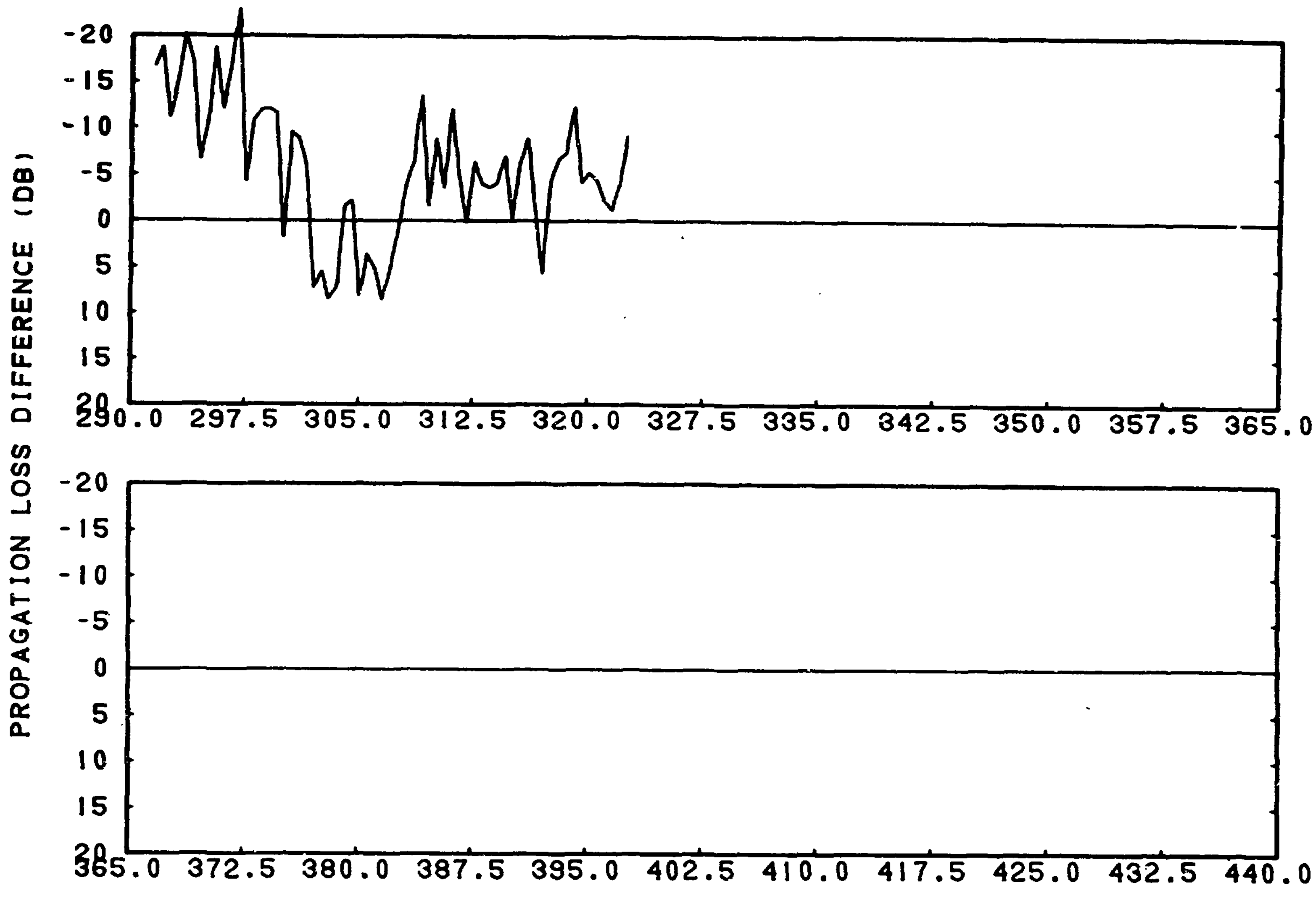
(C) Figure IIIE-73. RAYMODE Coherent, Bottom Loss = MGS 7, Run 12D, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 305 Meters, Sliding Averages of 5 Points (2.00 Kilometers)



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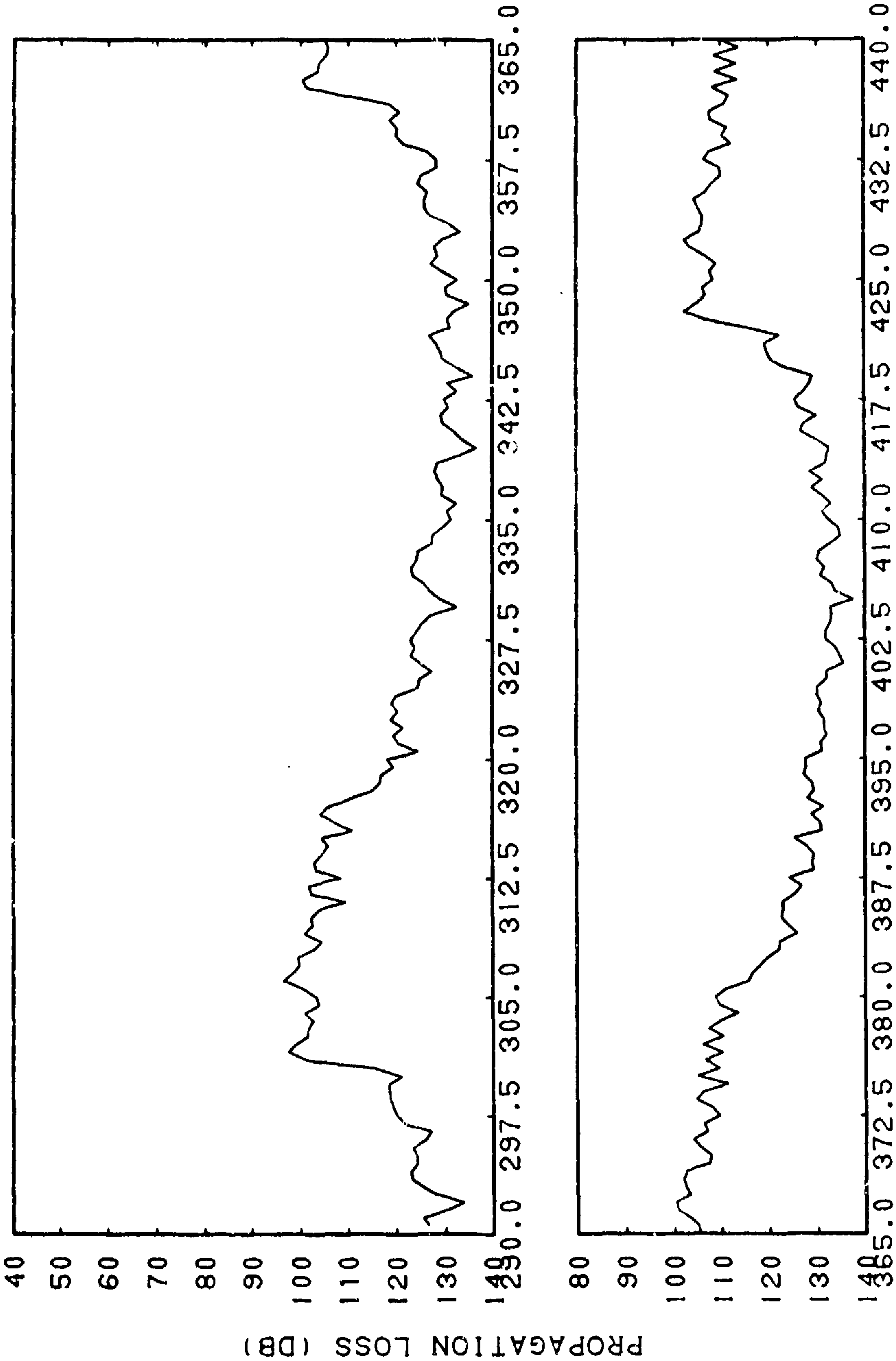
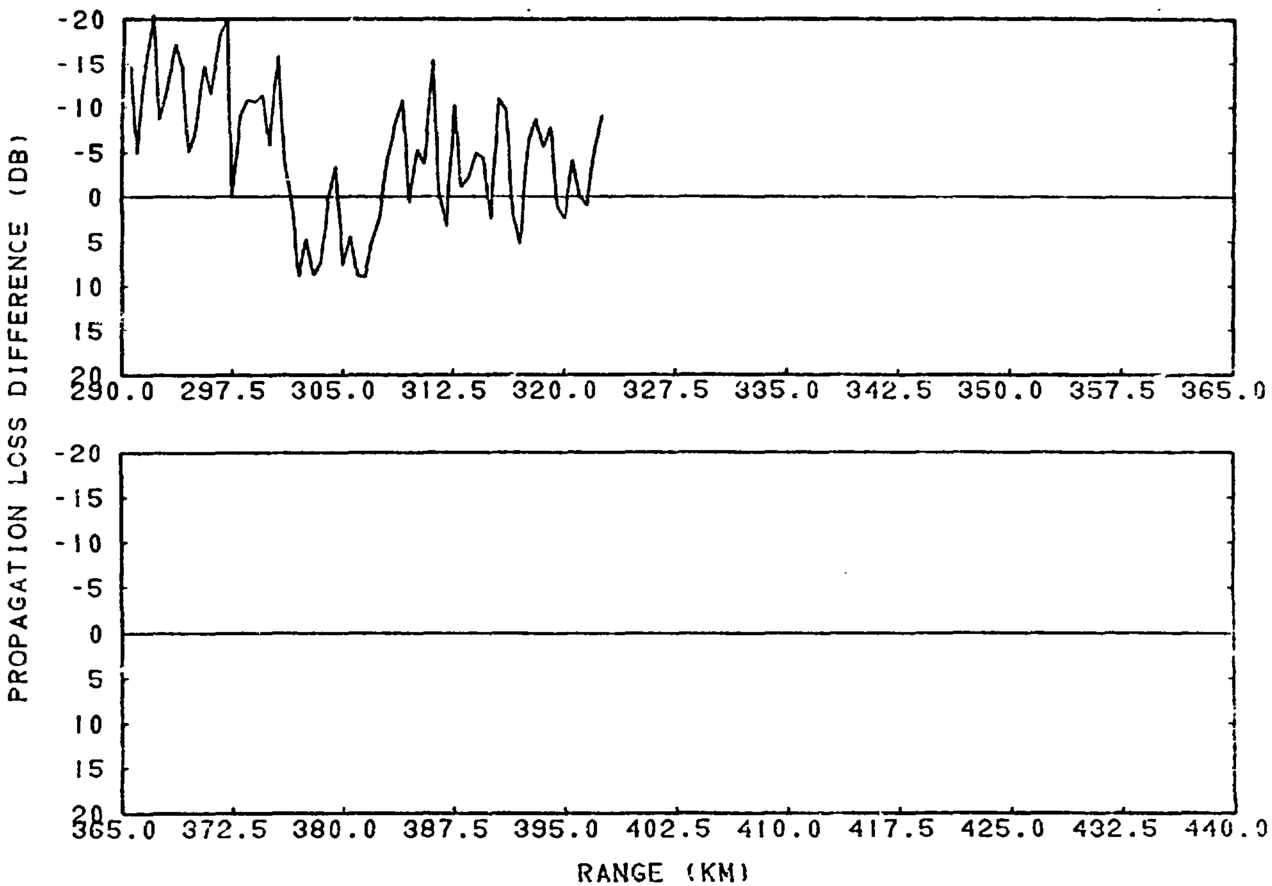
(C) Figure IIIE-74. Smoothed RAYMODE Coherent, Bottom Loss = MGS 7, Run 12D, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 305 Meters, Subtracted from LORAD Data, Run 12D, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 305 Meters

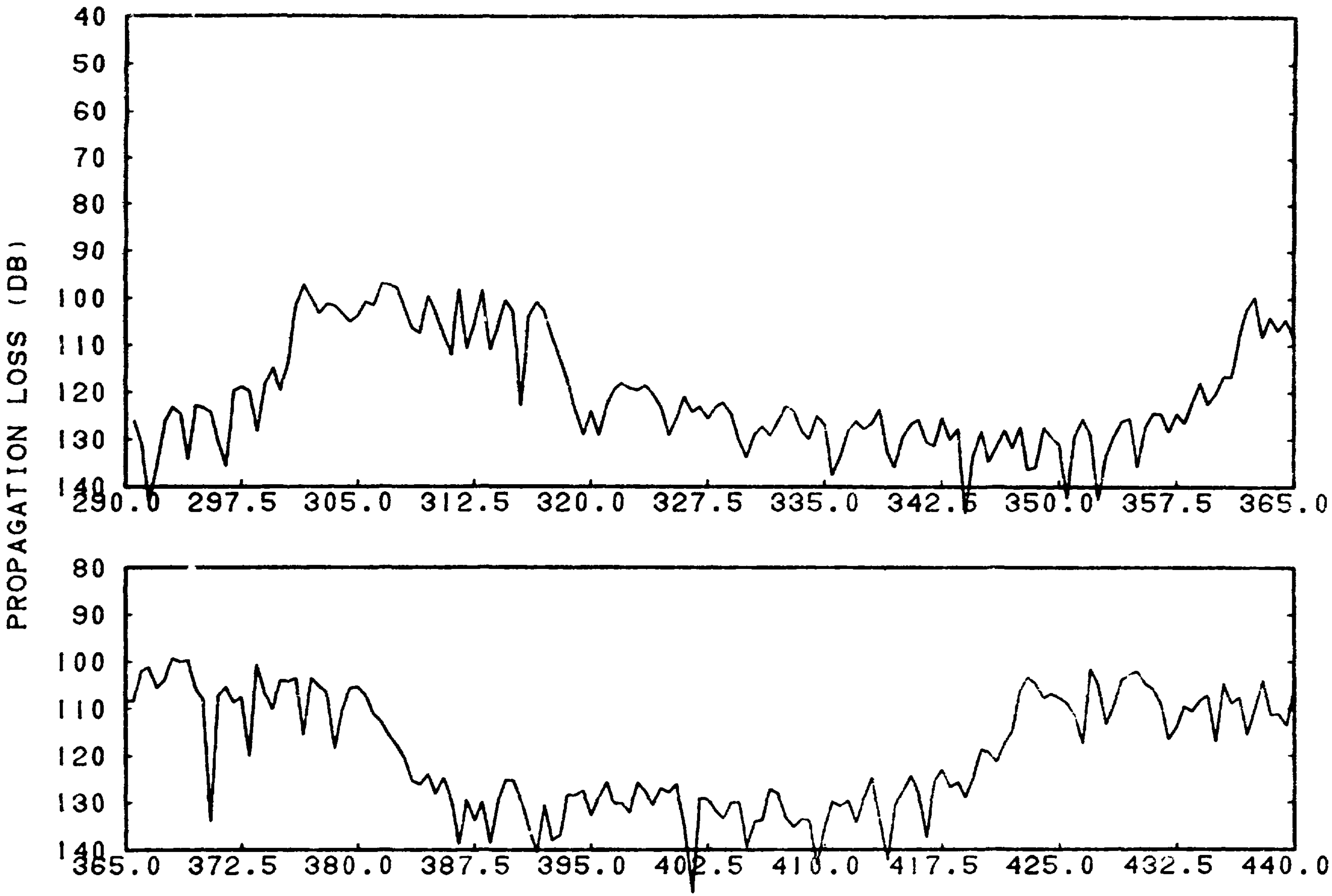


(C) Figure IIIE-75. RAYMODE Incoherent, Bottom Loss = MGS 7, Run 12D, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 305 Meters



CONFIDENTIAL

(C) Figure IIIE-76. RAYMODE Incoherent, Bottom Loss = MGS 7, Run 12D, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 305 Meters, Subtracted from LORAD Data, Run 12D, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 305 Meters



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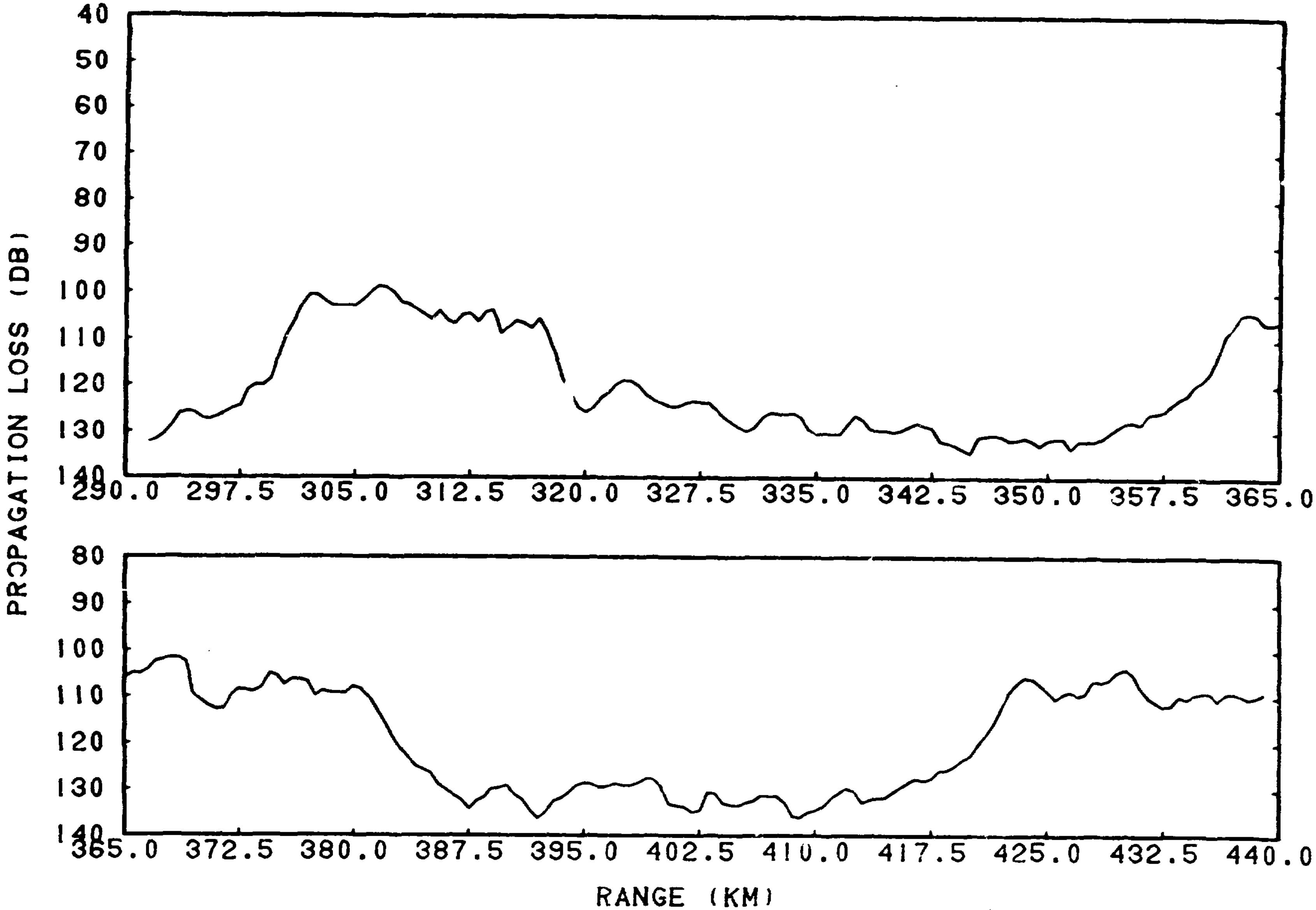
(C) Figure IIIE-77. RAYMODE Coherent, Bottom Loss = MGS 7, Run 14D, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 305 Meters



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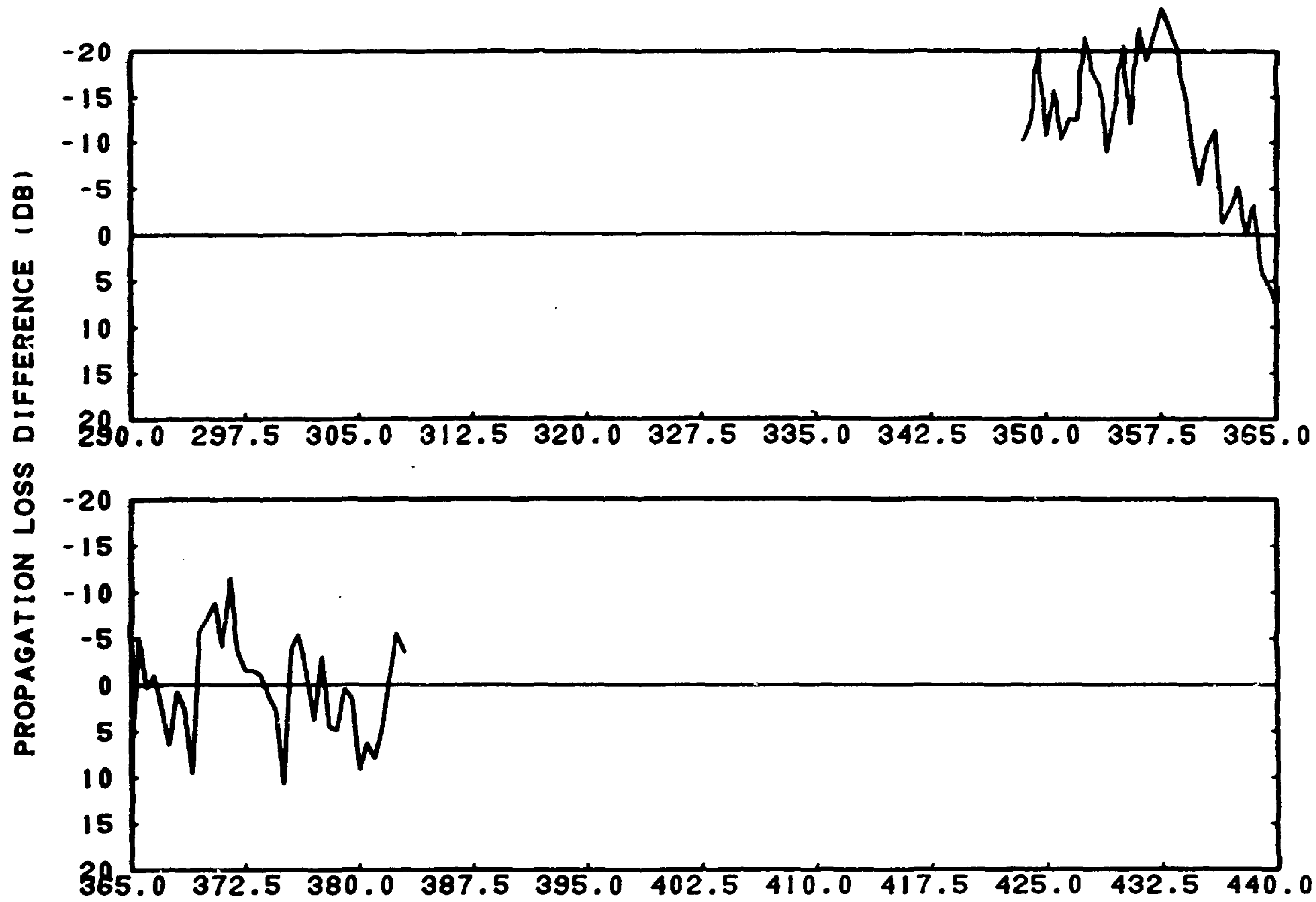
(C) Figure IIIE-78. RAYMODE Coherent, Bottom Loss = MGS 7, Run 14D, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 305 Meters, Sliding Averages of 5 Points (2.00 Kilometers)



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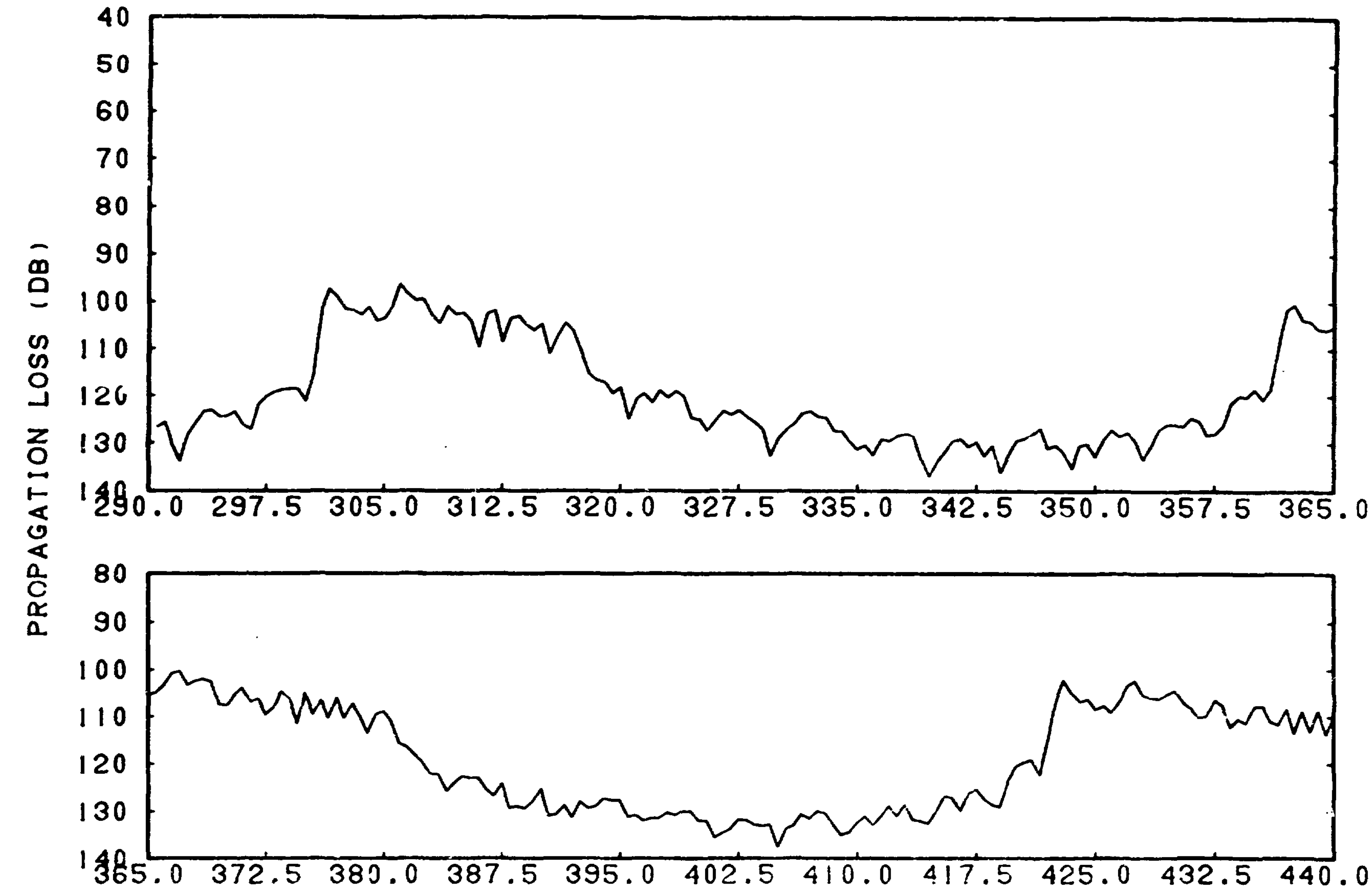
(C) Figure IIIE-79. Smoothed RAYMODE Coherent, Bottom Loss = MGS 7, Run 14D, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 305 Meters, Subtracted from LORAD Data, Run 14D, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 305 Meters



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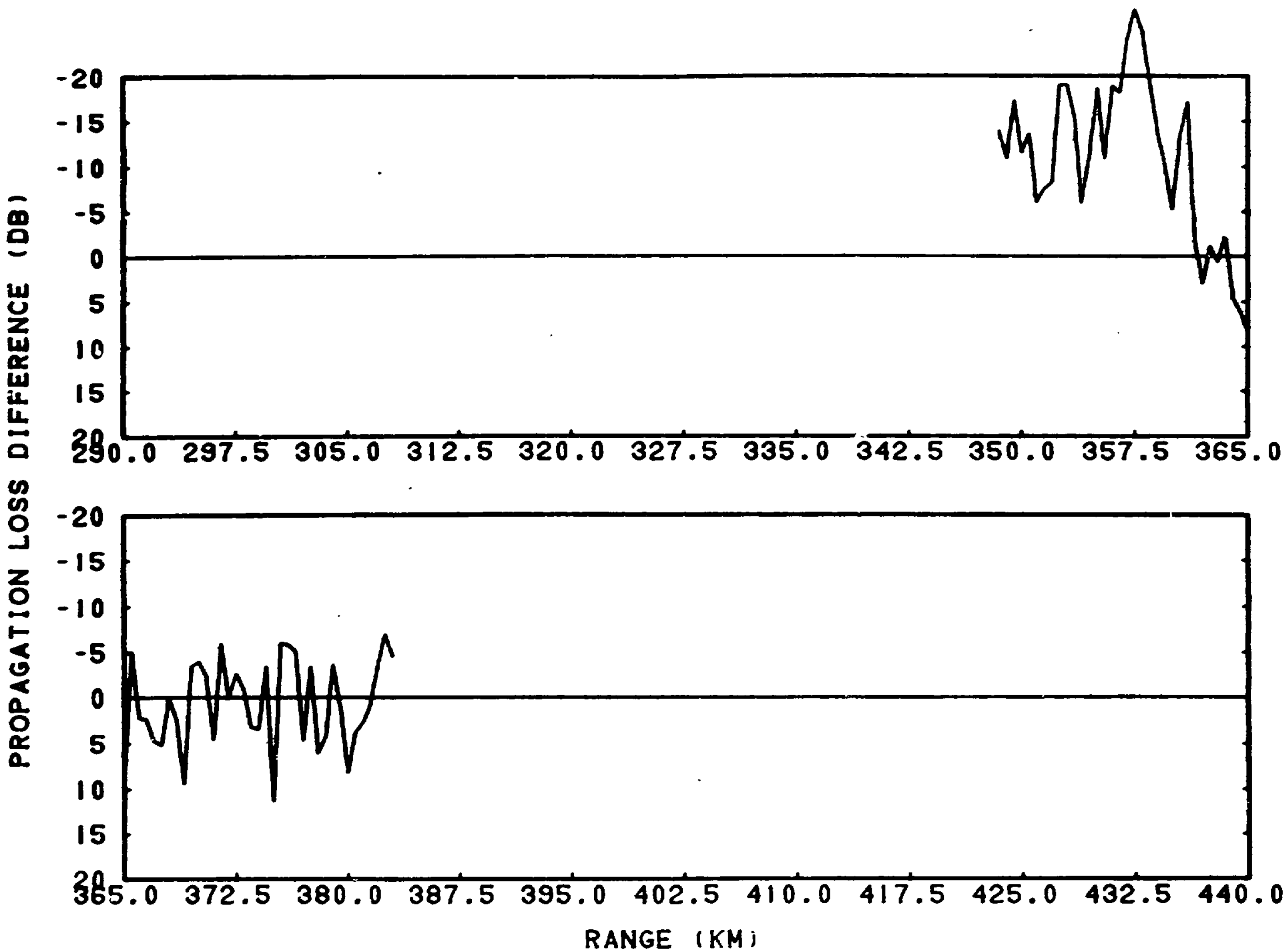
(C) Figure IIIE-80. RAYMODE Incoherent, Bottom Loss = MGS 7, Run 14D, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 305 Meters



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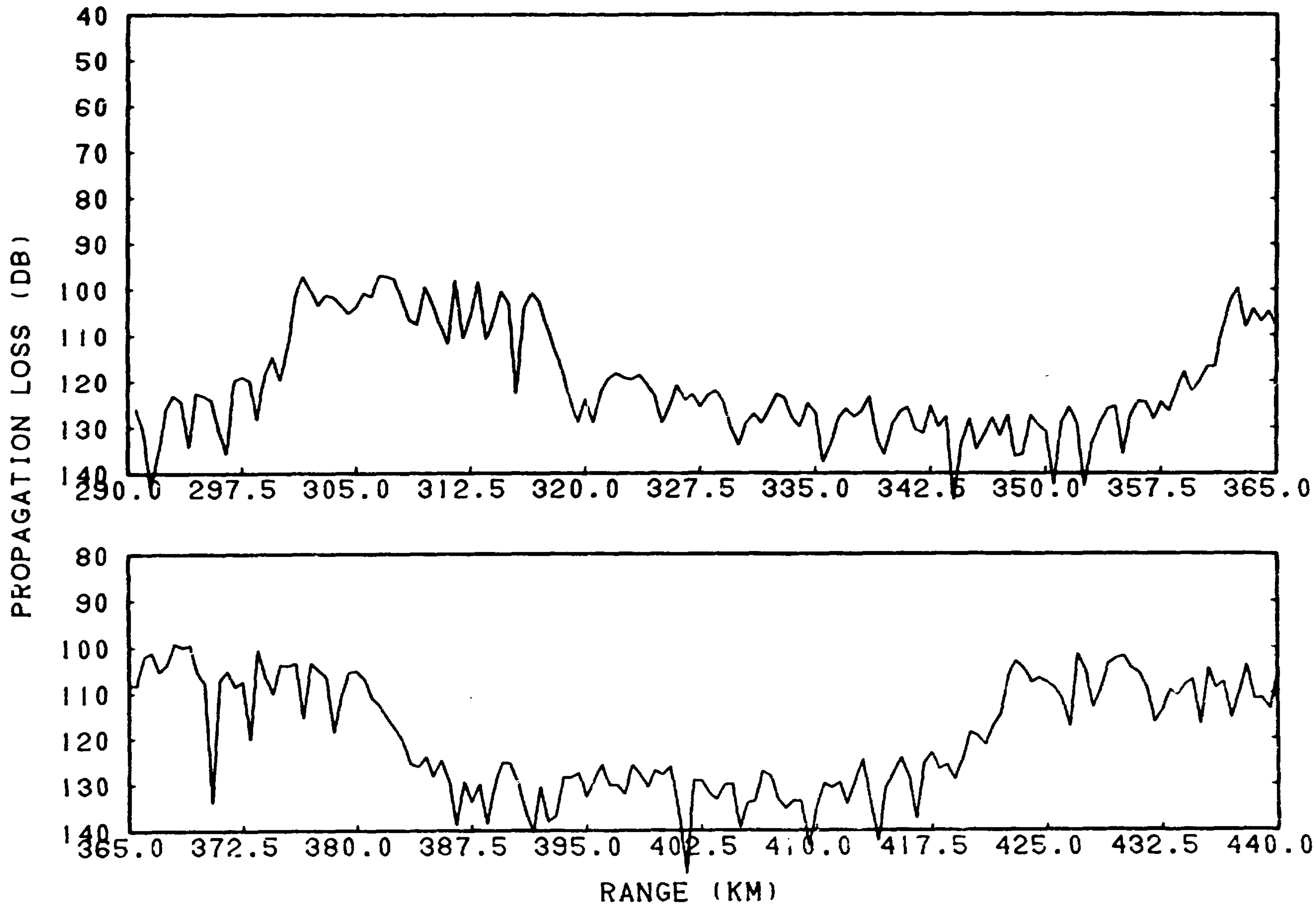
(C) Figure IIIE-81. RAYMODE Incoherent, Bottom Loss = MGS 7, Run 14D, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 305 Meters, Subtracted from LORAD Data, Run 14D, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 305 Meters



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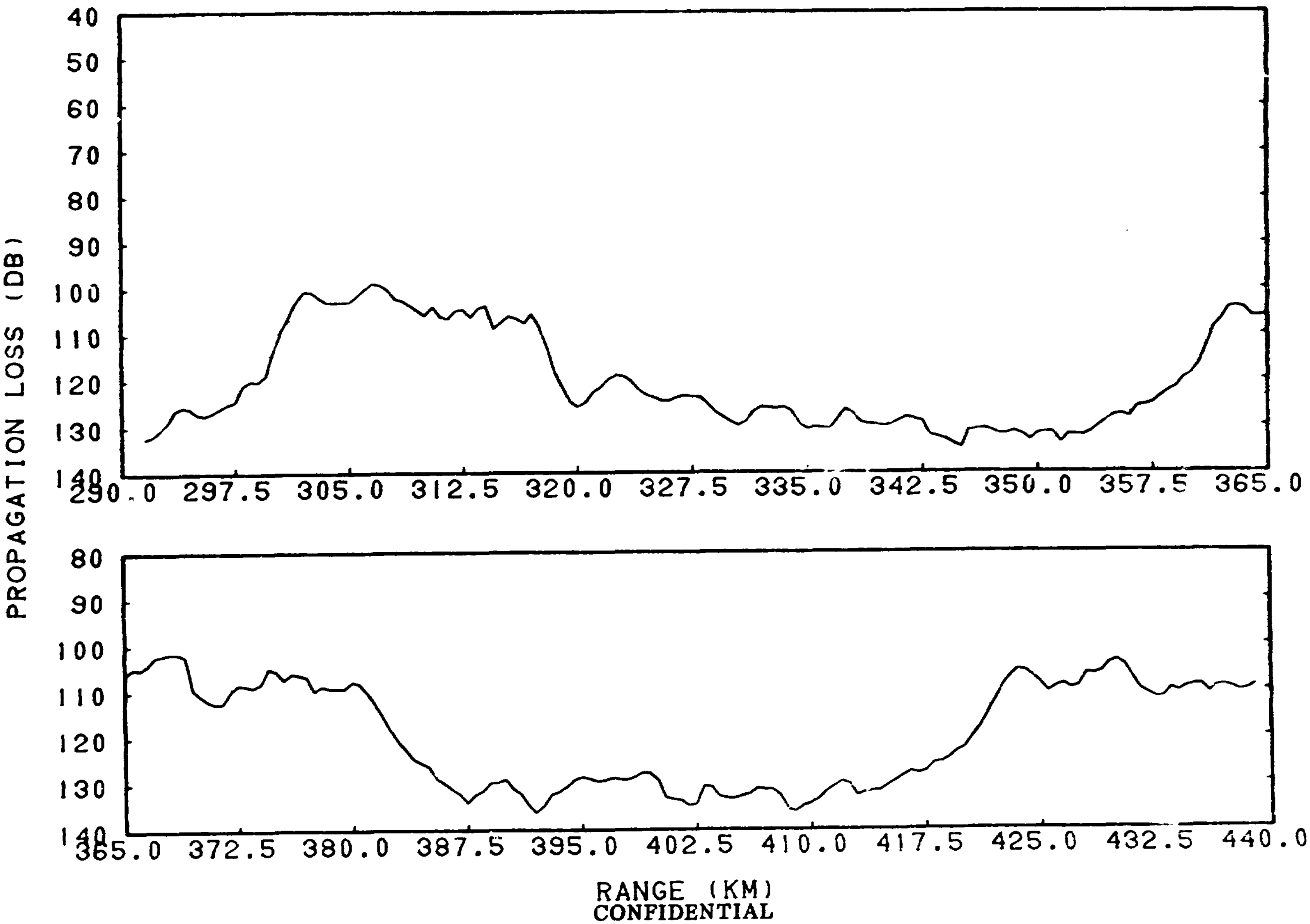
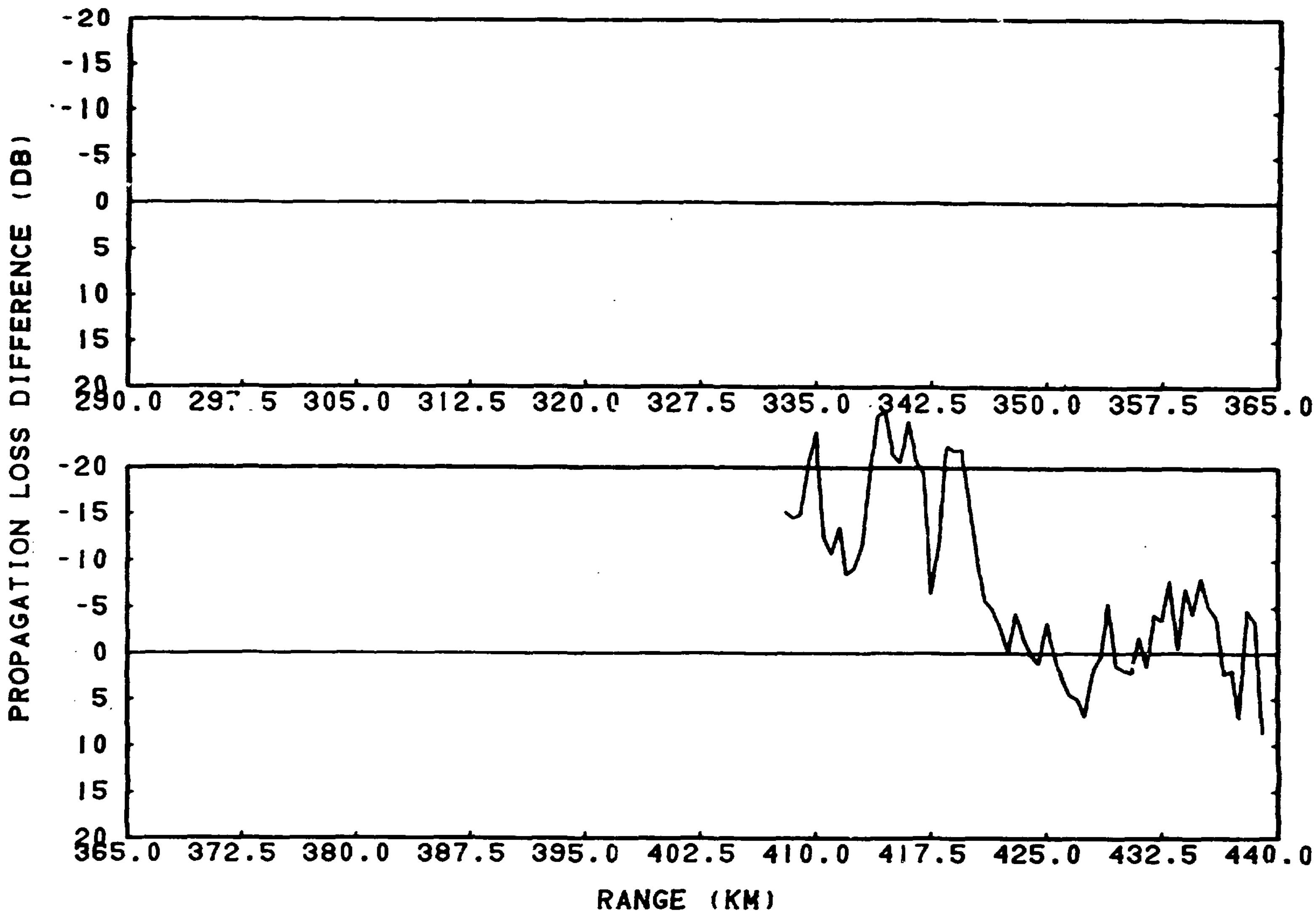
(C) Figure IIIE-82. RAYMODE Coherent, Bottom Loss = MGS 7, Run 16D, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 305 Meters



(C) Figure IIIE-83. RAYMODE Coherent, Bottom Loss = MGS 7, Run 15D, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 305 Meters, Sliding Averages of 5 Points (2.00 Kilometers)



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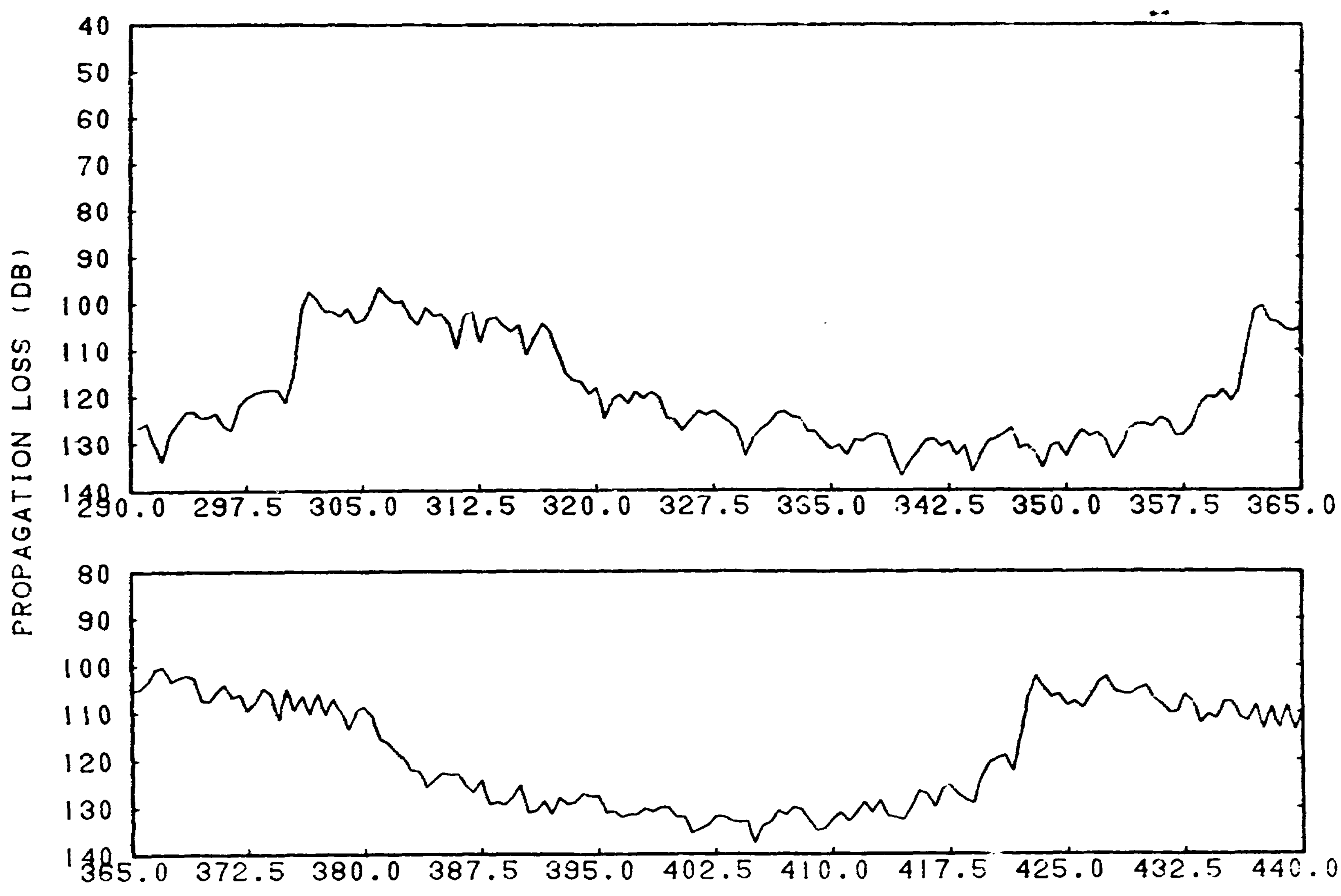
(C) Figure IIIE-84. Smoothed RAYMODE Coherent, Bottom Loss = MGS 7, Run 16D, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 305 Meters, Subtracted from LORAD Data, Run 16D, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 305 Meters



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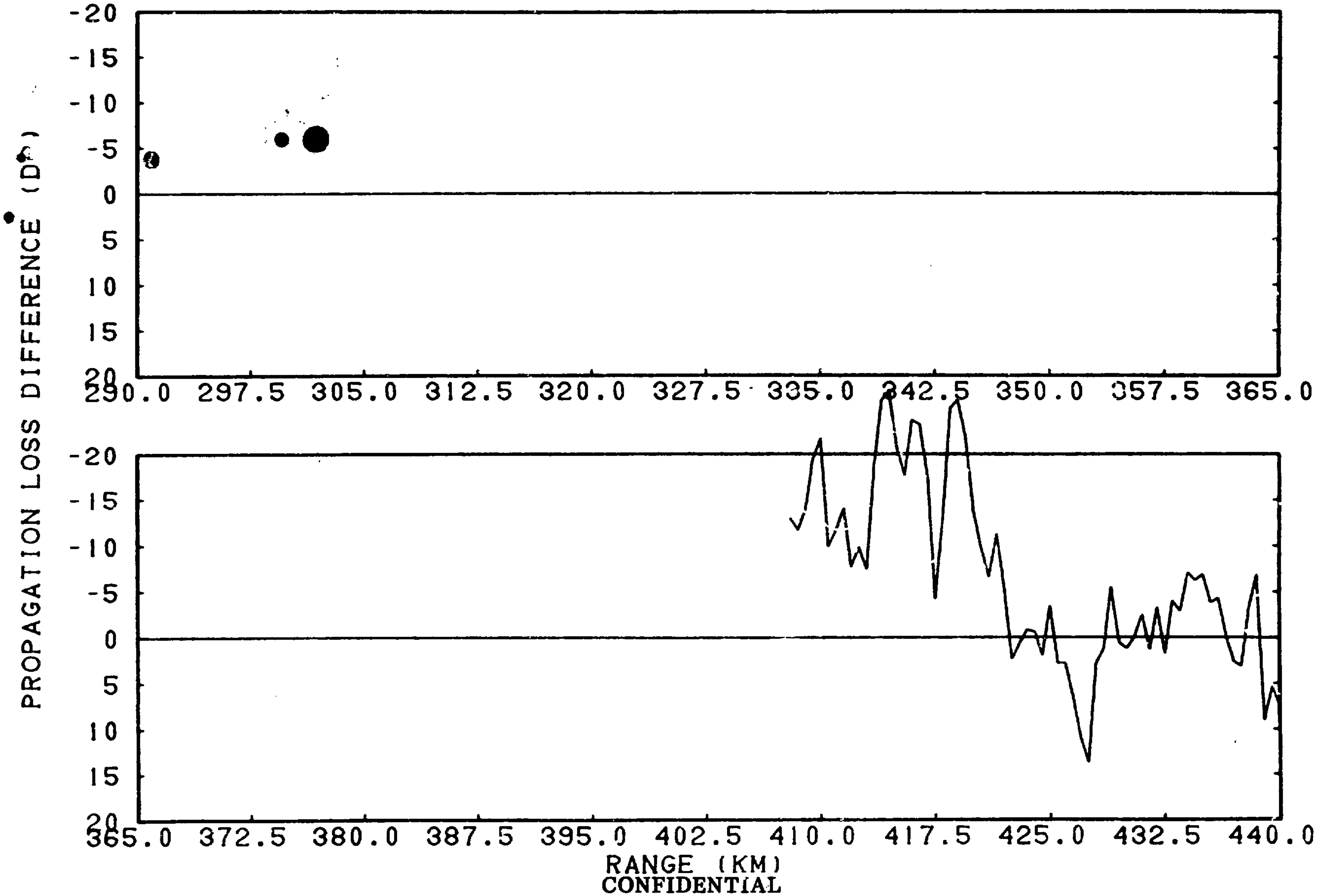
(C) Figure IIIE-85. RAYMODE Incoherent, Bottom Loss = MGS 7, Run 16D, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 305 Meters



(C) Figure IIIE-86. RAYMODE Incoherent, Bottom Loss = MGS 7, Run 16D, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 305 Meters, Subtracted from LORAD Data, Run 16D, Frequency = 0.53 Kilohertz, Source Depth = 15 Meters, Receiver Depth = 305 Meters

Appendix IIIF. Accuracy Assessment of RAYMODE X Compared to Joast III Experimental Data (U)

Joast III (U)

Environment (U)

(U) The JOAST III environments used for RAYMODE X model evaluation test cases are stations 1, 2, 3, and 5. The sound speed versus depth profiles for these stations are plotted and tabulated in Figures IIIF-1 to IIIF-4. The sound speed profile for station 1 has a slightly negative gradient layer overlying a sound channel with axis at 137 m. Bottom depth is 2816 m and a positive depth excess of approximately 700 m is observed. The sound speed profile for station 2 has a negative gradient layer to 18.3 m above a sound channel with an axis depth of 61 m. The critical depth (i.e., depth at which the surface sound speed is again encountered) is 1530 m and the bottom depth is 2725 m. The positive depth excess is therefore 1195 m. The sound speed profile for station 3 is similar to that for station 2. A slightly negative gradient surface layer to 18.3 m overlies a sound channel with axis at 70 m. The critical depth is at 1998 m and the bottom depth is 3471 m, yielding a positive depth excess of 1473 m. The sound speed profile for station 5 is unique among the JOAST stations in that a positive gradient surface duct extends to 44.2 m above a slightly negative gradient layer to a depth of 149.6 m at which point a deep sound channel begins. The deep sound channel axis is at 442.3 m, the critical depth at approximately 1900 m and the bottom at 2743 m, giving a positive depth excess of 843 m.

(U) The bottom loss versus grazing angle curves for stations 1 and 2 are given in Figure IIIF-5, for station 3 in Figure IIIF-6, and for station 5 in Figure III-F-7. Bottom loss versus grazing angle for stations 1 and 2 is tabulated in Table IIIF-1, for station 3 in Table IIIF-2 and for station 5 in Table IIIF-3. The curve for stations 1 and 2 is FNOC Type 2 having 3.5 dB loss at zero degrees, 4.8 dB loss at 15°, and 9 dB loss at normal incidence. For station 3 the bottom is FNOC Type 3 which is characterized by 5.8 dB bottom loss at zero degrees, 7.6 dB loss at 15° and 11.5 dB loss at 90° (a maximum loss of 11.6 dB is found from 76 to 80°). For station 5, an FNOC Type 8 bottom is found. At zero degrees the loss is 13.1 dB, at 15° the loss is 26.7 dB, and at normal incidence the loss is 25 dB. The bottom loss versus grazing angle curve has two local maxima: 28.2 dB at 24° and 26.5 dB at 80°.

(U) The use of FNOC bottom loss versus grazing angle curves rather than the internal (MGS) RAYMODE X curves has an insignificant effect on zone start and end ranges.

Test Cases (U)

(C) Fourteen test cases were chosen from the Joint Oceanographic Acoustic and System Test (JOAST) III results. For all cases but one the receivers were the uppermost (60 ft), middle (260 ft), and lowest (535 ft) hydrophones of a vertical array. The JOAST III experiment covered all Mediterranean Basins (see Martin, 1982, for details). In all cases the source was an AN/SQS-26 sonar transmitting pulsed signals at a frequency of 3700 Hz. The source was at a depth of 20 feet. Data were obtained by towing the vertical array through the first convergence zone while the source remained in fixed position. Ranges were precisely determined by radio link. A list of the test cases is shown on the following page.

Case	Station	Run	Receiver Depth (ft)	Figure
I	1	43	60	IIIF8a-f
II	1	43	260	IIIF9a-f
III	1	43	535	IIIF10a-f
IV	2	63	60	IIIF11a-f
V	2	63	260	IIIF12a-f
VI	2	63	535	IIIF13a-f
VII	3	43	60	IIIF14a-f
III	3	43	260	IIIF15a-f
IX	3	43	535	IIIF16a-f
X	3	103	50	IIIF17a-f
XI	3	93	535	IIIF18a-f
XII	5	43	60	IIIF19a-f
XIII	5	43	260	IIIF20a-f
XIV	5	43	1000	IIIF21a-f

Accuracy Assessment Results (U)

(C) The accuracy assessment procedures were followed as outlined in section 1.1 and described in detail in volume I of this series with the exception that in the Difference Technique means and standard deviations were not calculated. These calculations were omitted since a slight error in convergence zone range leads to a large value for the standard deviation which can be easily misinterpreted as an error in convergence zone shape.

(U) The following figures were produced for each case: (a) JOAST experimental data, (b) RAYMODE X output using the coherent option, (c) the coherent result smoothed by application of a 2 km window running average, (d) the smoothed coherent result subtracted from the JOAST experimental data, (e) RAYMODE X output using the incoherent phase addition option, and (f) the incoherent result subtracted from JOAST data. The figures corresponding to the fourteen cases are listed above.

(U) The results of the figure of merit versus detection range analyses are given in Tables IIIF-4 through IIIF-17.

(C) The results for each case are summarized below.

(C) Case I (Station 1, Run 43, Source/Receiver Depth = 20 ft/260 ft)

The start ranges for the JOAST and RAYMODE convergence zones are in close agreement for FOM $\leq$ 90 dB. For FOM = 95 dB the JOAST CZ start is at longer range than RAYMODE's by 1 dB for the coherent option, 2 km for the incoherent result. This is due to the presence of bottom bounce energy in the model result. At FOM = 100 dB the RAYMODE CZ start is short by 3 km due to bottom bounce broadening. The JOAST CZ end is 1 to 3 km beyond that of RAYMODE. Both RAYMODE and JOAST have peak values of 79 dB. The shapes of JOAST and RAYMODE are identical to FOM = 95 dB. The downward slope at the top of the CZ is continued further in RAYMODE than in JOAST.

(C) Case II (Station 1, Run 43, Source/Receiver Depth = 20 ft/260 ft)

The start ranges for JOAST and RAYMODE are in close agreement for all values of FOM and a bottom bounce plateau at the same level. The RAYMODE CZ is broader than that of JOAST by 2-3 km. The peak

levels for both JOAST and RAYMODE are at 85 dB. The shapes are quite similar except for the extension of the RAYMODE CZ.

(C) Case III (Station 1, Run 43, Source/Receiver Depth = 20 ft/535 ft)

The CZ starts are identical for FOM < 100 dB. At FOM = 105 dB, the start is altered by the presence of bottom bounce energy. The RAYMODE CZ is approximately 2 km broader than that of JOAST. The CZ envelopes have basically the same shape aside from the extension of the RAYMODE convergence zone compared to that of JOAST. Both have peak levels of 87 dB. The smoothed coherent RAYMODE result shows four lobes whereas the JOAST data suggests only two lobes.

(C) Case IV (Station 2, Run 63, Source/Receiver Depth = 20 ft/60 ft)

The shapes of the JOAST and RAYMODE X convergence zones are quite similar with both start and end ranges in basic agreement. The peak value in the JOAST data is 74 dB (a spike at the start of the CZ) and RAYMODE (coherent) has a peak value of 77 dB. Both data sets show fluctuations--about 10 dB for JOAST and 15-25 dB for RAYMODE. The effect of bottom bounce at CZ start is evident at a 10 dB lower level for RAYMODE (i.e., less loss) than for JOAST.

(C) Case V (Station 2, Run 63, Source/Receiver Depth = 20 ft/260 ft)

The convergence zone starts are in basic although variable agreement, generally within 1 km at all values of figure of merit. Agreement of CZ end ranges is within 0.5 km at most figures of merit. The shapes of the envelopes are in good agreement and both model and experimental data show fluctuations of about 5 dB. The CZ peaks are 83 dB for RAYMODE X and 85 dB for JOAST. Both JOAST and RAYMODE have a double lobe near the start of the convergence zone.

(C) Case VI (Station 2, Run 63, Source/Receiver Depth = 20 ft/535 ft)

The envelopes of the JOAST and RAYMODE results are similar for the incoherent option but the RAYMODE CZ start is 1-1.5 km earlier than JOAST's. Both results show a slight double lobe near the start of the convergence zone. The coherent RAYMODE output and JOAST show similarity in shape but RAYMODE has generally 3 dB less loss than JOAST. In the FOM analysis, this difference translates into a longer CZ end for RAYMODE (by 1 to 2.5 km). Peak levels are 83 dB for JOAST and 82 dB for RAYMODE X.

(U) Case VII (Station 2, Run 43, Source/Receiver Depth = 20 ft/ 60 ft)

The convergence zone predicted by RAYMODE (coherent) is identical in shape to the JOAST and both show fluctuations of about 15 dB. Bottom bounce energy affects the CZ end for RAYMODE at FOM = 90 dB in marked contrast to that of JOAST data. JOAST and RAYMODE both have peak levels of 78 dB.

(U) Case VIII (Station 3, Run 43, Source/Receiver Depth = 20 ft/260 ft)

The RAYMODE X coherent output is displaced to lower loss by 3-4 dB and to longer range by 2 kilometers. The effect of bottom loss broadens the RAYMODE convergence zone for figures of merit greater than 90 dB.

(U) Case IX (Station 3, Run 43, Source/Receiver Depth = 20 ft/ 535 ft)

For FOM = 90 dB the JOAST CZ onset occurs 3 km before RAYMODE coherent, but 1.5 km before RAYMODE incoherent. The zone with 5 km for JOAST is 1-1.5 km greater than RAYMODE's. For FOM = 95 dB JOAST zone start is 1-2 km before RAYMODE's and width is the same as RAYMODE incoherent. For FOM ≥ 100 dB the CZ is corrupted by bottom bounce energy for RAYMODE.

(C) Case X (Station 3, Run 103, Source/ Receiver Depth = 20 ft/60 ft)

The envelopes of the JOAST and RAYMODE X data envelopes are in basic agreement. However, the end of the RAYMODE X coherent CZ is indistinct due to bottom loss energy. The peak level of JOAST data is 77 dB and of RAYMODE is 78 dB. The CZ start ranges for JOAST and RAYMODE are in close agreement as are the CZ ends until at FOM = 90 dB the bottom bounce energy in the RAYMODE prediction makes it difficult to define the convergence zone's end.

(C) Case XI (Station 3, Run 93, Source/ Receiver Depth = 20 ft/535 ft)

In this case, there is a cluster of eight points between 83 and 91 dB that appear anomalous in the JOAST data at the start of the convergence zone. Even with the points eliminated, however, it would require a 1 km shift to shorter range and a 2 dB shift to higher loss in the RAYMODE X prediction to bring it in line with the JOAST data. Bottom bounce energy renders the range of the RAYMODE zone end uncertain for FOM > 90 dB. The effect of the aforementioned cluster of points is evident in the short CZ start ranges for JOAST compared to RAYMODE at FOMs of 85 and 90 dB.

(C) Case XII (Station 5, Run 43, Source/ Receiver Depth = 20 ft/60 ft)

The JOAST convergence zone is found in the same range interval as the RAYMODE X prediction but the latter is shifted in acoustic level to 10 dB less propagation loss. The RAYMODE prediction is in line with other predictions for this source/ receiver combination although it is possible that the CZ is riding on and modulating a surface duct effect. The cause of the disparity is uncertain from the analysis undertaken and may be due to erroneous JOAST data, an erroneous sound speed profile, or an overly optimistic prediction due to the surface duct module in the RAYMODE X model.

(C) Case XIII (Station 5, Run 43, Source/ Receiver Depth = 20 ft/260 ft)

In this case, as in the last, a shift of the RAYMODE X coherent prediction to 10 dB greater loss would bring it into almost perfect agreement with the JOAST data. As before, the cause of this discrepancy cannot be established from the analysis undertaken.

(C) Case XIV (Station 5, Run 43, Source/ Receiver Depth = 20 ft/1000 ft)

As in the previous two cases of station 5, run 43, a 10 dB shift to greater loss would bring RAYMODE X into substantial agreement with JOAST experimental results.

General Conclusions (U):

(C) RAYMODE X predictions and JOAST experimental data were in basically good agreement with regard to convergence zone shape, peak level, start range, and zone duration. Exceptions are (1) in cases II and III the RAYMODE CZ end was broader by about 2-3 km than that of JOAST and (2) the RAYMODE and JOAST CZs were displaced in level by 10 dB (JOAST exhibiting greater loss) in cases XII-XIV. The use of FNOC bottom loss may have been responsible for the greater evidence of bottom loss contamination of the convergence zone (particularly at its end) for the RAYMODE predictions as compared to JOAST data. This is true for station 3 where relatively less loss were predicted from the FNOC bottom loss charts (FNOC Type 2 for station 2 and FNOC Type 3 for station 3). This is not true for stations 1 and 2 where both are characterized by FNOC Type 2 and MGS Type 2 bottom losses (Note: The FNOC and MGS bottom loss versus grazing angle curves generally differ, but for a Type 2 bottom the difference is less than 1 dB over the full angular extent).

References (U)

Martin, R. L., et al. (1982). Summary of Range Independent Environment Acoustic Propagation Data Sets (U). Vol. IA, The Acoustic Model Evaluation Committee (AMEC) Reports, NORDA Report 34, Naval Ocean Research and Development Activity, NSTL Station, Miss. (CONFIDENTIAL)

(C) Table IIIF-1. Bottom Loss (dB) Versus Grazing Angle (degrees) for JOAST III Stations 1 and 2. FNOC Type 2. Frequency = 3.7 kHz.

Θ	BL	Θ	BL	Θ	BL	Θ	BL	Θ	BL	Θ	BL	Θ	BL
0	3.49	13	4.56	26	6.03	39	7.40	52	8.37	65	8.85	78	8.96
1	3.54	14	4.66	27	6.15	40	7.49	53	8.43	66	8.87	79	8.96
2	3.60	15	4.77	28	6.26	41	7.58	54	8.48	67	8.89	80	8.96
3	3.67	16	4.88	29	6.37	42	7.67	55	8.53	68	8.90	81	8.96
4	3.74	17	5.00	30	6.48	43	7.75	56	8.57	69	8.91	82	8.96
5	3.81	18	5.11	31	6.59	44	7.83	57	8.61	70	8.92	83	8.96
6	3.89	19	5.22	32	6.70	45	7.91	58	8.65	71	8.93	84	8.96
7	3.98	20	5.34	33	6.81	46	7.98	59	8.69	72	8.94	85	8.96
8	4.07	21	5.45	34	6.91	47	8.06	60	8.72	73	8.95	86	8.97
9	4.16	22	5.57	35	7.01	48	8.13	61	8.75	74	8.95	87	8.97
10	4.25	23	5.69	36	7.11	49	8.19	62	8.78	75	8.95	88	8.98
11	4.35	24	5.80	37	7.21	50	8.26	63	8.81	76	8.96	89	8.99
12	4.45	25	5.92	38	7.31	51	8.32	64	8.83	77	8.96	90	9.00

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(C) Table IIIF-2. Bottom Loss (dB) Versus Grazing Angle (degrees) for JOAST III Station 3. FNOC Type 3. Frequency = 3.7 kHz.

Θ	BL	Θ	BL	Θ	BL	Θ	BL	Θ	BL	Θ	BL	Θ	BL
0	5.79	13	7.39	26	8.83	39	10.03	52	10.92	65	11.45	78	11.62
1	5.91	14	7.50	27	8.94	40	10.11	53	10.97	66	11.48	79	11.62
2	6.04	15	7.62	28	9.04	41	10.19	54	11.02	67	11.50	80	11.62
3	6.16	16	7.74	29	9.14	42	10.27	55	11.07	68	11.52	81	11.61
4	6.29	17	7.85	30	9.23	43	10.34	56	11.12	69	11.54	82	11.60
5	6.41	18	7.97	31	9.33	44	10.41	57	11.17	70	11.56	83	11.59
6	6.54	19	8.08	32	9.42	45	10.49	58	11.21	71	11.57	84	11.58
7	6.66	20	8.19	33	9.52	46	10.55	59	11.25	72	11.59	85	11.57
8	6.78	21	8.30	34	9.61	47	10.62	60	11.29	73	11.60	86	11.56
9	6.90	22	8.41	35	9.70	48	10.68	61	11.33	74	11.61	87	11.54
10	7.03	23	8.52	36	9.78	49	10.75	62	11.36	75	11.61	88	11.52
11	7.15	24	8.63	37	9.87	50	10.81	63	11.39	76	11.62	89	11.50
12	7.27	25	8.73	38	9.95	51	10.86	64	11.42	77	11.62	90	11.48

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(C) Table IIIF-3. Bottom Loss (dB) Versus Grazing Angle (degrees) for JOAST III Station 5. FNOC Type 8. Frequency = 3.7 kHz.

θ	BL	θ	BL	θ	BL	θ	BL	θ	BL	θ	BL	θ	BL
0	13.07	13	25.83	26	28.12	39	26.52	52	25.10	65	25.39	78	26.42
1	14.61	14	26.28	27	28.07	40	26.37	53	25.06	66	25.48	79	26.44
2	16.05	15	26.67	28	28.00	41	26.22	54	25.03	67	25.56	80	26.45
3	17.38	16	27.01	29	27.91	42	26.08	55	25.01	68	25.65	81	26.44
4	18.61	17	27.30	30	27.80	43	25.94	56	25.00	69	25.74	82	26.40
5	19.74	18	27.54	31	27.69	44	25.81	57	25.01	70	25.84	83	26.32
6	20.78	19	27.73	32	27.56	45	25.69	58	25.02	71	25.93	84	26.26
7	21.73	20	27.89	33	27.43	46	25.58	59	25.05	72	26.02	85	26.14
8	22.60	21	28.00	34	27.28	47	25.47	60	25.08	73	26.10	86	25.49
9	23.39	22	28.09	35	27.13	48	25.38	61	25.13	74	26.18	87	25.81
10	24.11	23	28.14	36	26.98	49	25.29	62	25.18	75	26.26	88	25.59
11	24.75	24	28.16	37	26.83	50	25.22	63	25.25	76	26.32	89	25.32
12	25.32	25	28.15	38	26.68	51	25.15	64	25.32	77	26.38	90	25.01

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(C) Table IIF-4. Convergence Zone (CZ) Start and End Range[1] as a Function of Figure of Merit (FOM) for JOAST Experimental Data and RAYMODE X Predictions with Coherent[2], and Incoherent Phase Additions.
Case I.
(Station 1, Run 43, Source Depth = 20 ft., Receiver Depth = 60 ft., Frequency = 3.7 kHz)

FOM (dB)	Data Set	CZ Start Range (km)	CZ End Range (km)	Remarks
80	JOAST	39.0	40.5	
	RAYMODE Coherent	39.0	42.5	
	RAYMODE Incoherent	41.5	41.5	
85	JOAST	39.0	42.0	
	RAYMODE Coherent	38.5	45.0	
	RAYMODE Incoherent	38.5	41.0	
90	JOAST	38.0	43.5	
	RAYMODE Coherent	37.5	45.0	
	RAYMODE Incoherent	38.5	45.0	
95	JOAST	36.5	44.0	
	RAYMODE Coherent	34.5	45.5	CZ includes some buttom bounce energy
	RAYMODE Incoherent	35.5	45.5	Broadening of CZ due to bottom bounce
100	JOAST	36.0	44.5	
	RAYMODE Coherent	33.0	45.5	Broadening of CZ due to bottom bounce
	RAYMODE Incoherent			

1. Detection ranges accurate to ±0.25 km.
2. Coherent results are unsmoothed

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(C) Table IIIF-5. Convergence Zone (CZ) Start and End Ranges[1] as a Function of Figure of Merit (FOM) for JOAST Experimental Data and RAYMODE X Predictions with Coherent[2], and Incoherent Phase Additions.
Case II.
(Station 1, Run 43, Source Depth = 20 ft., Receiver Depth = 260 ft., Frequency = 3.7 kHz)

FOM (dB)	Data Set	CZ Start Range (km)	CZ End Range (km)	Remarks
85	JOAST	39.0	40.0	
	RAYMODE Coherent	40.5	40.5	Single spike
	RAYMODE Incoherent			
90	JOAST	38.5	41.0	
	RAYMODE Coherent	38.5	43.5	
	RAYMODE Incoherent	38.5	41.5	
95	JOAST	38.0	43.5	
	RAYMODE Coherent	38.0	45.5	
	RAYMODE Incoherent	38.0	45	
100	JOAST	35.5	43.5	
	RAYMODE Coherent	36.5	46.0	Slight broadening due to bottom bounce energy
	RAYMODE Incoherent		46.0	
105	JOAST	35.5	44.5	CZ start broadened by bottom bounce energy
	RAYMODE Coherent		46.0	
	RAYMODE Incoherent		46.5	

1. Detection ranges accurate to ±0.25 km.
2. Coherent results are unsmoothed.

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(C) Table IIIF-6. Convergence Zo (CZ) Start and End Ranges[1] as a Function of Figure of Merit (FOM) for JOAST Experimental Data and RAYMODE X Predictions with Coherent2, and Incoherent Phase Additions.
Case III.
(Station 1, Run 43, Source Depth = 20 ft., Receiver Depth = 535 ft., Frequency = 3.7 kHz)

FOM (dB)	Data Set	CZ Start Range (km)	CZ End Range (km)	Results
90	JOAST	38.0	42.0	
	RAYMODE Coherent	38.0	44.0	
	RAYMODE Incoherent	38.0	42.0	
95	JOAST	37.5	43.5	CZ double-lobed for FOM $\leq$ 103 dB
	RAYMODE Coherent	37.5	45.5	CZ multi-lobed for FOM $\leq$ 95
	RAYMODE Incoherent	37.5	44.5	
100	JOAST	37.0	43.5	
	RAYMODE Coherent	37.5	44.0	
	RAYMODE Incoherent		46	
105	JOAST	35.0	43.5	CZ start broadened by bottom bounce energy
	RAYMODE Coherent	38.0	46.0	Slight broadening due to bottom bounce energy
	RAYMODE Incoherent		46.0	
110	JOAST		45.0	
	RAYMODE Coherent		46.5	Broadening due to bottom bounce energy
	RAYMODE Incoherent			

1. Detection ranges accurate to ±0.25 km.
2. Coherent results are unsmoothed.

(C) Table IIIF-7. Convergence Zone (CZ) Start and End Ranges[1] as a Function of Figure of Merit (FOM) for JOAST Experimental Data and RAYMODE X Predictions with Coherent[2] and Incoherent Phase Additions.
Case IV.
(Station 2, Run 63, Source Depth = 20 ft., Receiver Depth = 60 ft., Frequency = 3.7 kHz)

FOM	Data Set	CZ Start Range (km)	CZ End Range (km)	Remark
80	JOAST	35.0	36.0	
	RAYMODE Coherent	35.0	37.0	
	RAYMODE Incoherent	35.0	36.0	
85	JOAST	35.0	38.5	
	RAYMODE Coherent	34.0	38.0	2 CZ peaks past 38 km
	RAYMODE Incoherent	34.0	37.0	
90	JOAST	35.0	41.0	
	RAYMODE Coherent	33.5	43.5	
	RAYMODE Incoherent	33.5	42.0	
95	JOAST	34.5	43.5	
	RAYMODE Coherent	33.5	43.5	CZ start includes bottom bounce broadening
	RAYMODE Incoherent	32.5	43.5	CZ start includes bottom bounce energy
100	JOAST	32.5	44	
	RAYMODE Coherent		43.5	
	RAYMODE Incoherent		43.5	
105	JOAST		44.5	
	RAYMODE Coherent		44.5	Broadening due to bottom bounce
	RAYMODE Incoherent		44.5	
110	JOAST		45.0	
	RAYMODE Coherent		44.5	Broadening due to bottom bounce
	RAYMODE Incoherent			

1. Detection ranges accurate to ±0.25 km.

2. Coherent results are unsmoothed.

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(C) Table IIIF-8. Convergence Zone (CZ) Start and End Ranges[1] as a Function of Figure of Merit (FOM) for JOAST Experimental Data and RAYMODE X Predictions with Coherent[2], and Incoherent Phase Additions.
Case V.
(Station 2, Run 63, Source Depth = 20 ft., Receiver Depth = 260 ft., Frequency = 3.7 kHz)

FOM (dB)	Data Set	CZ Start Range (km)	CZ End Range (km)	Remarks
85	JOAST	35.0	36.0	
	RAYMODE Coherent	34.0	36.5	
	RAYMODE Incoherent	34.0	36.5	
90	JOAST	35.0	38.5	
	RAYMODE Coherent	33.0	43.0	
	RAYMODE Incoherent	33.0	37.5	CZ multi-lobed for FOM ≤ 89 dB
95	JOAST	34.5	43.0	
	RAYMODE Coherent	33.0	43.0	CZ multi-lobed for FOM ≤ 95 dB
	RAYMODE Incoherent	33.0	43.0	
100	JOAST	32.0	44.0	
	RAYMODE Coherent	33.0	43.5	Slight broadening due to bottom bounce
	RAYMODE Incoherent		44.0	
105	JOAST	32.0	44.0	
	RAYMODE Coherent	33.0	44.0	Slight broadening due to bottom bounce
	RAYMODE Incoherent		44.0	
110	JOAST		45.5	
	RAYMODE Coherent	32.5	44.0	Slight broadening due to bottom bounce
	RAYMODE Incoherent		44.0	

1. Detection ranges accurate to ±0.25 km.

2. Coherent results are unsmoothed.

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(C) Table IIIF-9. Convergence Zone (CZ) Start and End Ranges[1] as a Function of Figure of Merit (FOM) for JOAST Experimental Data and RAYMODE X Predictions with Coherent[2], and Incoherent Phase Additions.
Case VI.
(Station 2, Run 63, Source Depth = 20 ft., Receiver Depth = 535 ft., Frequency = 3.7 kHz)

FOM (dB)	Data Set	CZ Start Range (km)	CZ End Range (km)	Remarks
85	JOAST	37.0	37.0	
	RAYMODE Coherent	34.0	38.0	
	RAYMODE Incoherent	36.5	37.0	
90	JOAST	34.5	39.0	
	RAYMODE Coherent	33.5	42.5	
	RAYMODE Incoherent	33.0	38.0	
95	JOAST	34.0	42.0	
	RAYMODE Coherent	31.0	44.0	
	RAYMODE Incoherent	32.5	43.0	CZ multi-lobed for FOM ≤ 91 dB
100	JOAST	32.0	44.5	
	RAYMODE Coherent	31.0	44.0	CZ start includes bottom bounce < 90 dB
	RAYMODE Incoherent		44.0	
105	JOAST	32.0	44.5	
	RAYMODE Coherent	31.0	44.5	CZ start includes bottom bounce effect
	RAYMODE Incoherent		44.5	
110	JOAST		44.5	
	RAYMODE Coherent	33.5	44.5	Slight broadening due to bottom bounce
	RAYMODE Incoherent		50.0	

1. Detection ranges accurate to ±0.25 km.

2. Coherent results are unsmoothed.

(C) Table IIIF-10. Convergence Zone (CZ) Start and End Ranges[1] as a Function of Figure of Merit (FOM) for JOAST Experimental Data and RAYMODE X Predictions with Coherent[2], and Incoherent Phase Additions.
Case VII.
(Station 3, Run 43, Source Depth = 20 ft., Receiver Depth = 60 ft., Frequency = 3.7 kHz)

FOM (dB)	Data Set	CZ Start Range (km)	CZ End Range (km)	Remarks
80	JOAST	40.0	42.0	
	RAYMODE Coherent	40.5	42.0	
	RAYMODE Incoherent	40.5	42.0	
85	JOAST	39.5	42.5	
	RAYMODE Coherent	39.0	43.0	
	RAYMODE Incoherent	39.0	42.0	
90	JOAST	39.0	44.0	
	RAYMODE Coherent	38.5	46.5	CZ includes broadening due to bottom bounce energy
	RAYMODE Incoherent	39.0	44.0	CZ is multi-lobed for FOM ≤ 86 dB CZ includes broadening due to bottom bounce energy
95	JOAST	39.0	44.5	
	RAYMODE Cohe ent	38.0		CZ is multi-lobed for FOM ≤ 95 dB CZ is highly broadened due to bottom bounce energy
	RAYMODE Incoherent	34.5		CZ is highly broadeded due to bottom bounce
100	JOAST	39.0	44.5	
	RAYMODE Coherent			CZ is highly broadened due to bottom bounce energy
	RAYMODE Incoherent			

1. Detection range accurate to ±0.25 km.

2. Coherent results are unsmoothed.

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(C) Table IIIF-11. Convergence Zone (CZ) Start and End Ranges[1] as a Function of Figure of Merit (FOM) for JOAST Experimental Data and RAYMODE X Predictions with Coherent[2], and Incoherent Phase Additions.
Case VIII.
(Station 3, Run 43, Source Depth = 20 ft., Receiver Depth = 260 ft., Frequency = 3.7 kHz)

FOM (dB)	Data Set	CZ Start Range (km)	CZ End Range (km)	Remarks
85	JOAST			
	RAYMODE Coherent	40.5	42.5	
	RAYMODE Incoherent	41	41	
90	JOAST	38.5	42.5	
	RAYMODE Coherent	39.5	43.5	
	RAYMODE Incoherent	39.5	42.5	
95	JOAST	38.5	43.0	
	RAYMODE Coherent	39.0		CZ is broadened due to bottom bounce energy
	RAYMODE Incoherent	38.0	43	Broadening due to bottom bounce energy
100	JOAST	38.5	44.5	
	RAYMODE Coherent			CZ highly broadened due to bottom bounce
	RAYMODE Incoherent			CZ highly broadened due to bottom bounce
105	JOAST	37.0	45.0	
	RAYMODE Coherent			CZ highly broadened due to bottom bounce
	RAYMODE Incoherent			

1. Detection ranges accurate to ±0.25 km.
2. Coherent results are unsmoothed.

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(C) Table IIIF-12. Convergence Zone (CZ) Start and End Ranges[1] as a Function of Figure of Merit (FOM) for JOAST Experimental Data and RAYMODE X Predictions with Coherent[2], and Incoherent Phase Additions.
Case IX.
(Station 3, Run 43, Source Depth = 20 ft., Receiver Depth = 535 ft., Frequency = 3.7 kHz)

FOM (dB)	Data Set	CZ Start Range (km)	CZ End Range (km)	Remarks
85	JOAST	38.0	38.0	A single point
	RAYMODE Coherent	41.0	42.5	
	RAYMODE Incoherent	41.5	41.5	A single point
90	JOAST	37.0	42.0	
	RAYMODE Coherent	40.0	43.5	
	RAYMODE Incoherent	38.5	42.5	
95	JOAST	37.0	43.0	
	RAYMODE Coherent	39.0	46.0	CZ end braodened by bottom bounce energy
	RAYMODE Incoherent	38.0	44.0	
100	JOAST	37.0	45.0	
	RAYMODE Coherent			
	RAYMODE Incoherent			
105	JOAST	37.0	48.5	CZ end may be broadened by noise or bottom bounce energy
	RAYMODE Coherent			
	RAYMODE Incoherent			

1. Detection ranges accurate to ± 0.25 km

2. Coherent results are unsmoothed

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(C) Table IIIF-13. Convergence Zone (CZ) Start and End Ranges[1] as a Function of Figure of Merit (FOM) for JOAST Experimental Data and RAYMODE X Predictions with Coherent[2], and Incoherent Phase Additions.
Case X.
(Station 3, Run 103, Source Depth = 20 ft., Receiver Depth = 60 ft., Frequency = 3.7 kHz)

FOM (dB)	Data Set	CZ Start Range (km)	CZ End Range (km)	Remarks
80	JOAST	39.0	41.0	
	RAYMODE Coherent	40.5	42.0	
	RAYMODE Incoherent	40.5	42.0	
85	JOAST	39.0	42.0	
	RAYMODE Coherent	39.0	42.5	
	RAYMODE Incoherent	39.0	42.0	CZ double-lobed for FOM ≤ 86 dB
90	JOAST	39.0	42.5	
	RAYMODE Coherent	38.0	46.0	CZ contains some bottom bounce energy
	RAYMODE Incoherent	39.0	44.0	
95	JOAST	39.0	47.5	
	RAYMODE Coherent	38.0	50.0	CZ broadened due to bottom bounce energy
	RAYMODE Incoherent			CZ broadened due to bottom bounce energy
100	JOAST	38.0	48.5	
	RAYMODE Coherent	38.0	50.0	CZ broadened due to bottom bounce energy
	RAYMODE Incoherent			CZ start broadened due to bottom bounce
105	JOAST	38.0	49.0	
	RAYMODE Coherent	38.0	50.0	CZ broadened due to bottom bounce energy
	RAYMODE Incoherent			
110	JOAST	37.0	49.5	
	RAYMODE Coherent	38.0	50.0	CZ broadened due to bottom bounce energy
	RAYMODE Incoherent			

1. Detection ranges accurate to ±0.25 km.

2. Coherent results are unsmoothed.

(C) Table IIIF-14. Convergence Zone (CZ) Start and End Ranges[1] as a Function of Figure of Merit (FOM) for JOAST Experimental Data and RAYMODE X Predictions with Coherent[2], and Incoherent Phase Additions.
Case XI.
(Station 3, Run 93, Source Depth = 20 ft., Receiver Depth = 535 ft., Frequency = 3.7 kHz)

FOM (dB)	Data Set	CZ Start Range (km)	CZ End Range (km)	Remarks
85	JOAST	38.0	38.0	
	RAYMODE Coherent	40.5	42.5	
	RAYMODE Incoherent	42.0	42.5	CZ is two spiked
90	JOAST	37.5	41.0	
	RAYMODE Coherent	40.5	44.0	
	RAYMODE Incoherent	37.5	43.0	
95	JOAST	38.5	43.0	
	RAYMODE Coherent	37.5	46.0	Broadening due to bottom bounce effects
	RAYMODE Incoherent	37.5	43.0	
100	JOAST	37.5	48.5	
	RAYMODE Coherent	32.5		CZ highly broadened due to bottom bounce energy
	RAYMODE Incoherent	33.0		CZ highly broadened due to bottom bounce energy
105	JOAST	37.0	43.5	
	RAYMODE Coherent	32.5		CZ highly broadened due to bottom bounce energy
	RAYMODE Incoherent	32.5		CZ highly broadened due to bottom bounce energy

1. Detection ranges accurate to ±0.25 km.

2. Coherent results are unsmoothed.

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(C) Table IIIF-15. Convergence Zone (CZ) Start and End Ranges[1] as a Function of Figure of Merit (FOM) for JOAST Experimental Data and RAYMODE X Predictions with Coherent[2], and Incoherent Phase Additions.
Case XII.
(Station 5, Run 43, Source Depth = 20 ft., Receiver Depth = 60 ft., Frequency = 3.7 kHz)

FOM (dB)	Data Set	CZ Start Range (km)	CZ End Range (km)	Remarks
80	JOAST			
	RAYMODE Coherent	42.5	45.0	
	RAYMODE Incoherent			
85	JOAST			
	RAYMODE Coherent	41.5	45.5	
	RAYMODE Incoherent	42.0	45.5	
90	JOAST	41.5	43.0	
	RAYMODE Coherent	41.5	46.5	
	RAYMODE Incoherent	41.5	46.0	
95	JOAST	41.5	44.5	
	RAYMODE Coherent	41.5	47.0	Slight broadening due to bottom bounce energy
	RAYMODE Incoherent			
100	JOAST	41.0	45.5	
	RAYMODE Coherent	41.0		
	RAYMODE Incoherent			

1. Detection range accurate to ±0.25 km.
2. Coherent results are unsmoothed.

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(C) Table IIIF-16. Convergence Zone (CZ) Start and End Ranges[1] as a Function of Figure of Merit (FOM) for JOAST Experimental Data and RAYMODE X Predictions with Coherent[2], and Incoherent Phase Additions.
Case XIII.
(Station 5, Run 43, Source Depth = 20 ft., Receiver Depth = 260 ft., Frequency = 3.7 kHz)

FOM (dB)	Data Set	CZ Start Range (km)	CZ End Range (km)	Remarks
80	JOAST			
	RAYMODE Coherent	41.0	41.0	Single spike
	RAYMODE Incoherent			
85	JOAST			
	RAYMODE Coherent	41.0	46.0	
	RAYMODE Incoherent	41.0	45.0	
90	JOAST	41.0	42.0	
	RAYMODE Coherent	41	46.5	
	RAYMODE Incoherent	41.0	46.0	
95	JOAST	40.0	43.5	
	RAYMODE Coherent	40.5	47.0	
	RAYMODE Incoherent	41.0	48.0	
100	JOAST	40.0	46.0	
	RAYMODE Coherent	39.5	48.0	
	RAYMODE Incoherent	40.0	50.0	CZ end broadened due to bottom bounce
105	JOAST	39.5	48.0	
	RAYMODE Coherent	39.0	49.0	Broadening due to bottom bounce effects
	RAYMODE Incoherent	35.5		

1. Detection ranges accurate to ±0.25 km.
2. Coherent results are unsmoothed.

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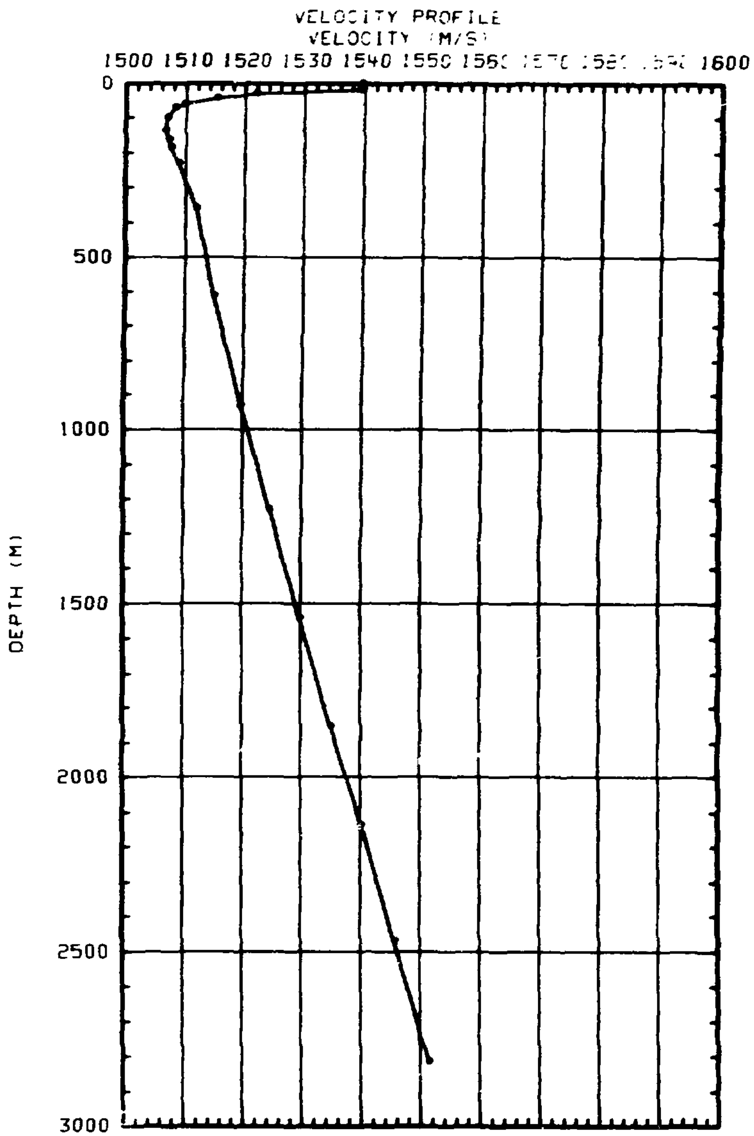
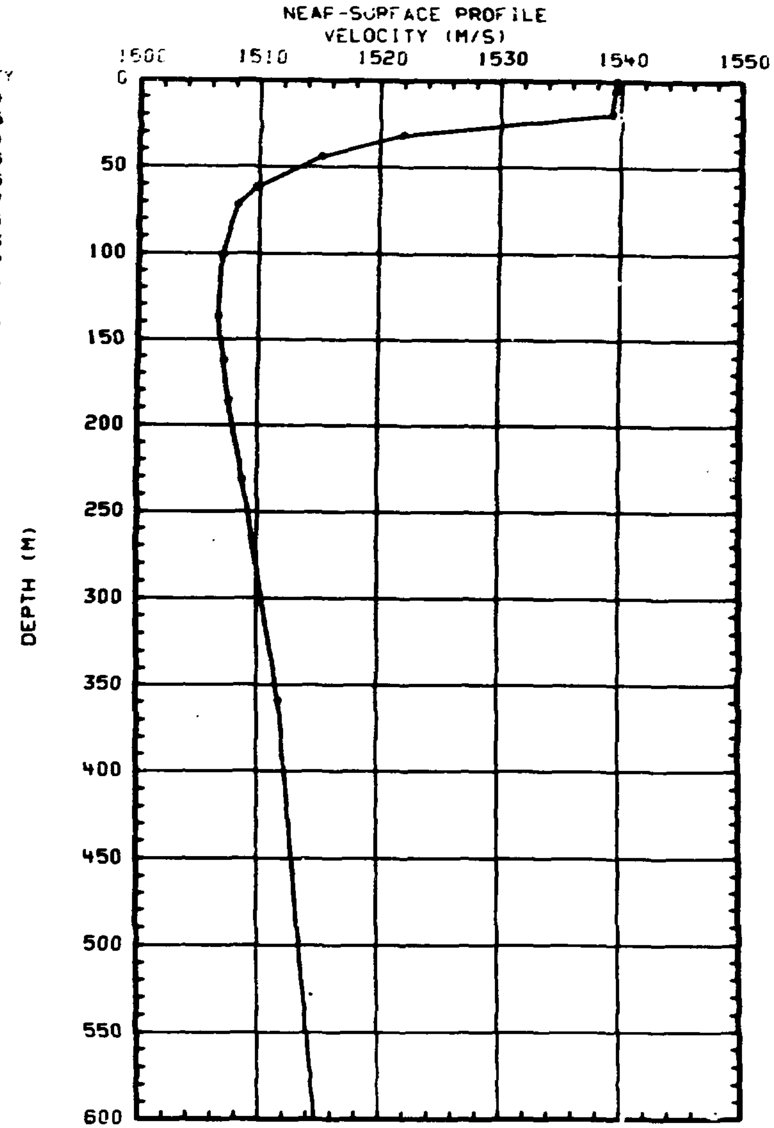
(C) Table IIIF-17. Convergence Zone (CZ) Start and End Ranges[1] as a Function of Figure of Merit (FOM) for JOAST Experimental Data and RAYMODE X Predictions with Coherent2, and Incoherent Phase Additions.
Case XIV.
(Station 5, Run 43, Source Depth = 20 ft., Receiver Depth = 1000 ft., Frequency = 3.7 kHz)

FOM (dB)	Data Set	CZ Start Range (km)	CZ End Range (km)	Remarks
85	JOAST			
	RAYMODE Coherent	39.0	39.5	
	RAYMODE Incoherent	39.5	39.5	
90	JOAST			
	RAYMODE Coherent	38.5	47.0	
	RAYMODE Incoherent	39.0	46.5	
95	JOAST			
	RAYMODE Coherent	38.5	47.5	
	RAYMODE Incoherent	39.0	47.5	
100	JOAST		42.5	
	RAYMODE Coherent	38.0	48.5	
	RAYMODE Incoherent	39.0	48.0	
105	JOAST		45.5	
	RAYMODE Coherent	38.5	50.0	
	RAYMODE Incoherent	38.0		
110	JOAST		47.0	
	RAYMODE Coherent	31.0	50.0	CZ start is broadened due to bottom bounce energy
	RAYMODE Incoherent	35.0		

1. Detection ranges accurate to ±0.25 km.
2. Coherent results are unsmoothed.



DEPTH	VELOCITY
0.0	1539.54
6.1	1539.45
19.5	1539.24
31.7	1521.86
44.5	1515.16
61.9	1509.67
71.9	1508.15
101.5	1506.93
137.2	1506.62
163.1	1507.10
186.5	1507.54
232.2	1508.76
359.7	1511.81
613.2	1514.86
934.2	1519.73
1229.3	1524.61
1542.9	1529.79
1853.8	1534.97
2137.6	1540.15
2471.3	1545.64
2816.3	1551.43



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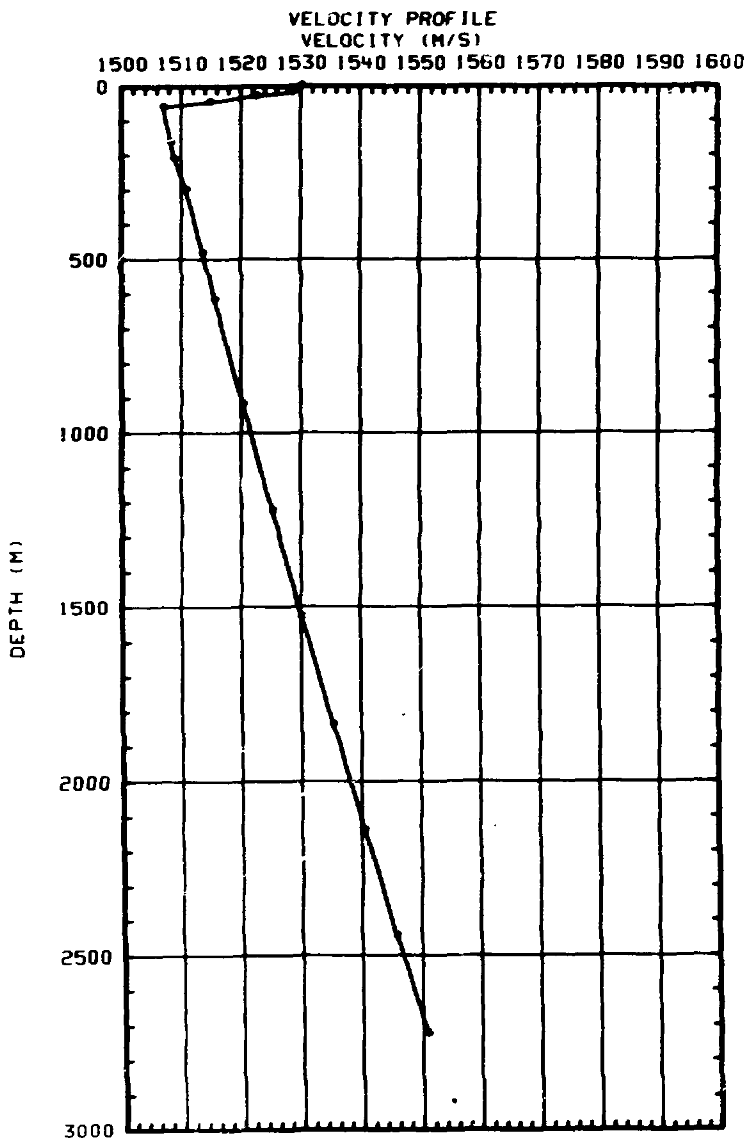
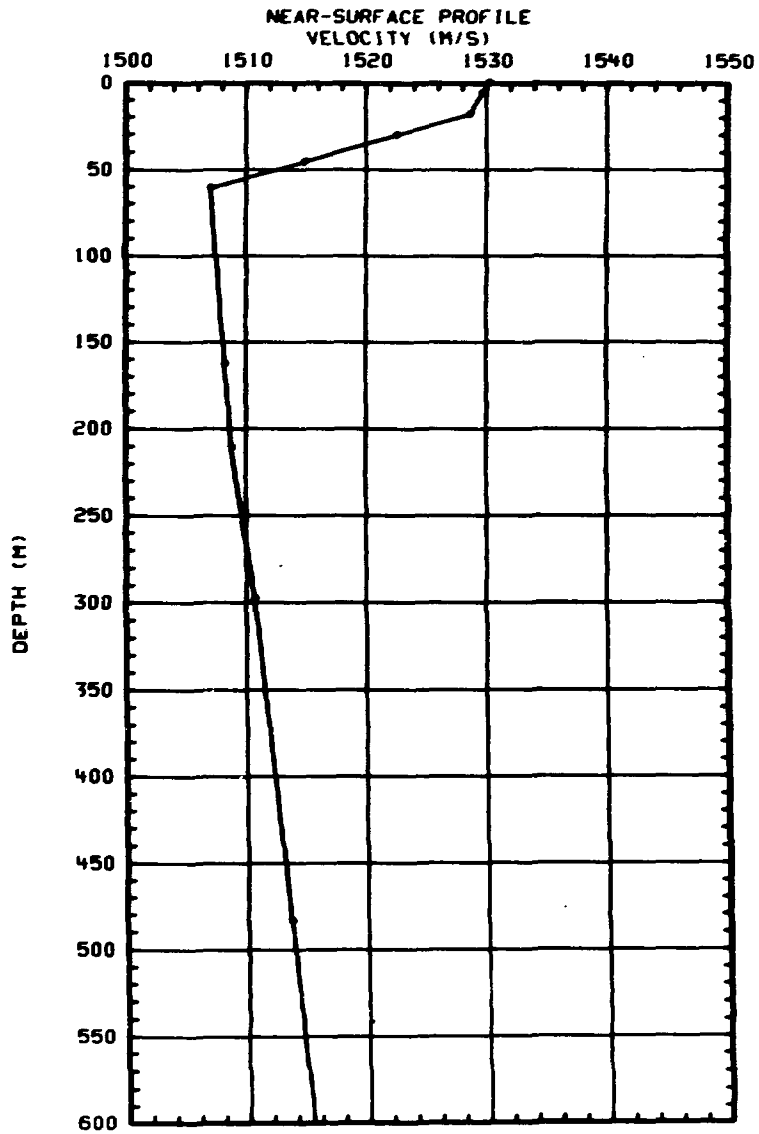
(U) Figure IIIF-1. JOAST Station 1 Sound Speed Profile



DEPTH	VELOCITY
0.0	1530.10
6.1	1529.60
18.3	1528.00
30.5	1522.50
45.7	1514.00
61.0	1507.00
163.1	1508.20
210.6	1508.70
298.1	1510.70
404.0	1513.60
618.7	1515.60
920.2	1520.30
1225.9	1525.20
1530.4	1530.10
1830.2	1535.30
2141.5	1540.50
2445.4	1545.70
2724.9	1550.80



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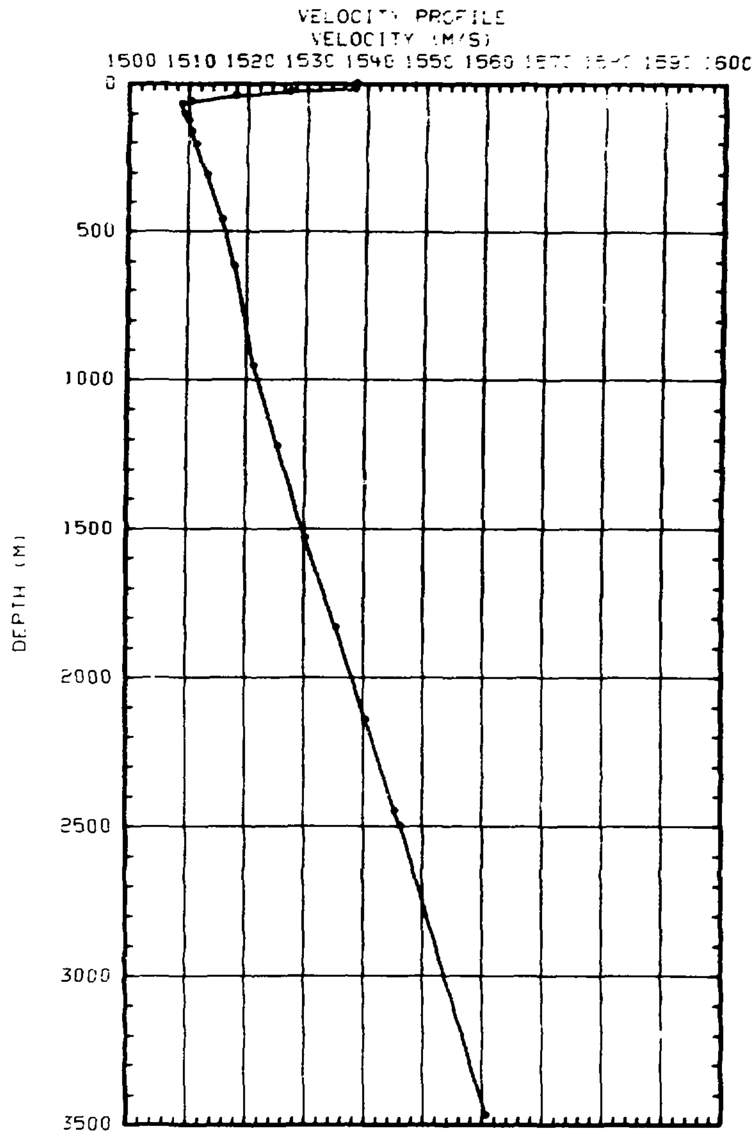
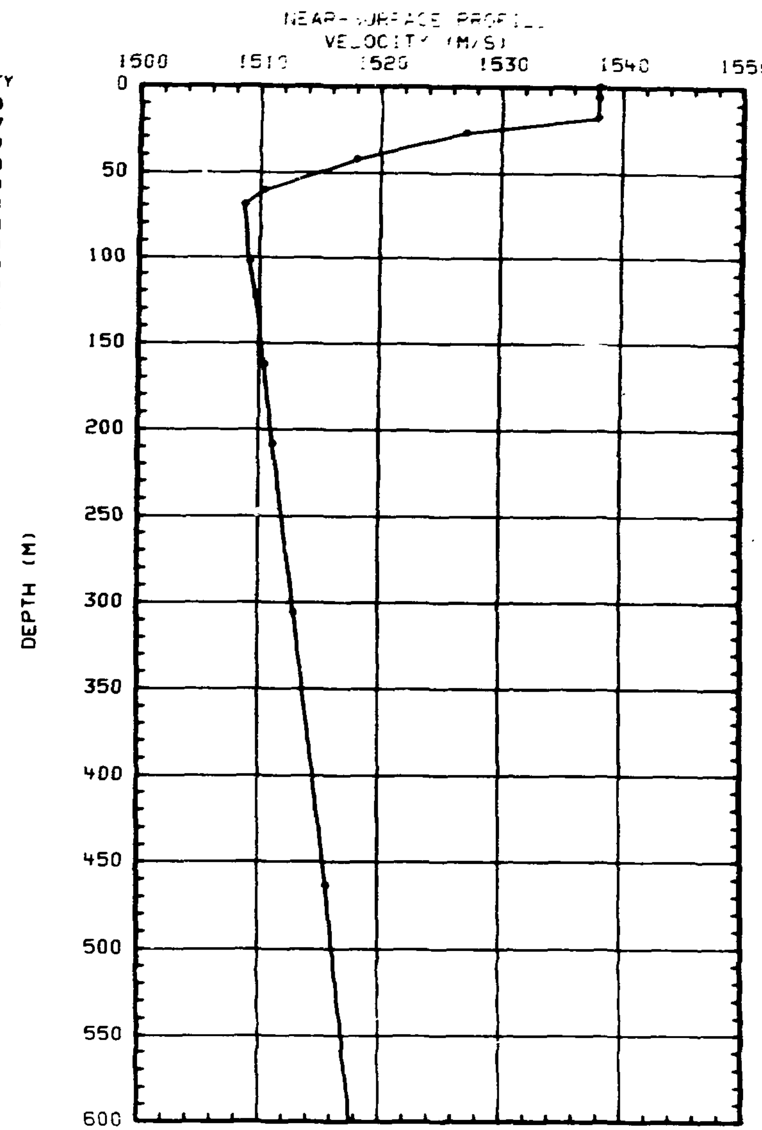
(U) Figure IIIF-2. JOAST Station 2 Sound Speed Profile

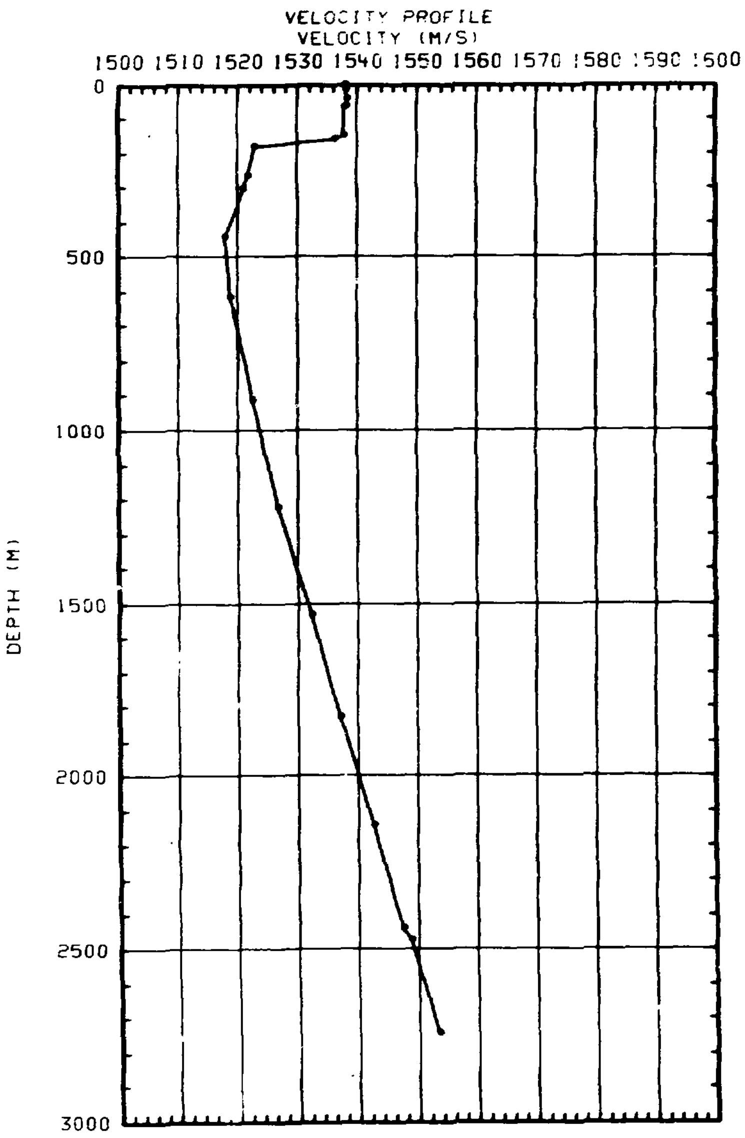


DEPTH	VELOCITY
0.0	1538.00
6.1	1537.97
18.3	1537.90
27.4	1527.00
42.7	1517.90
61.0	1510.30
70.1	1508.70
103.0	1509.10
123.4	1509.70
163.1	1510.40
208.8	1511.20
306.3	1513.00
463.9	1515.70
617.5	1517.90
955.5	1521.20
1224.7	1525.40
1534.1	1530.10
1833.7	1535.30
2143.3	1540.40
2450.6	1545.30
2500.6	1546.30
3471.1	1560.60

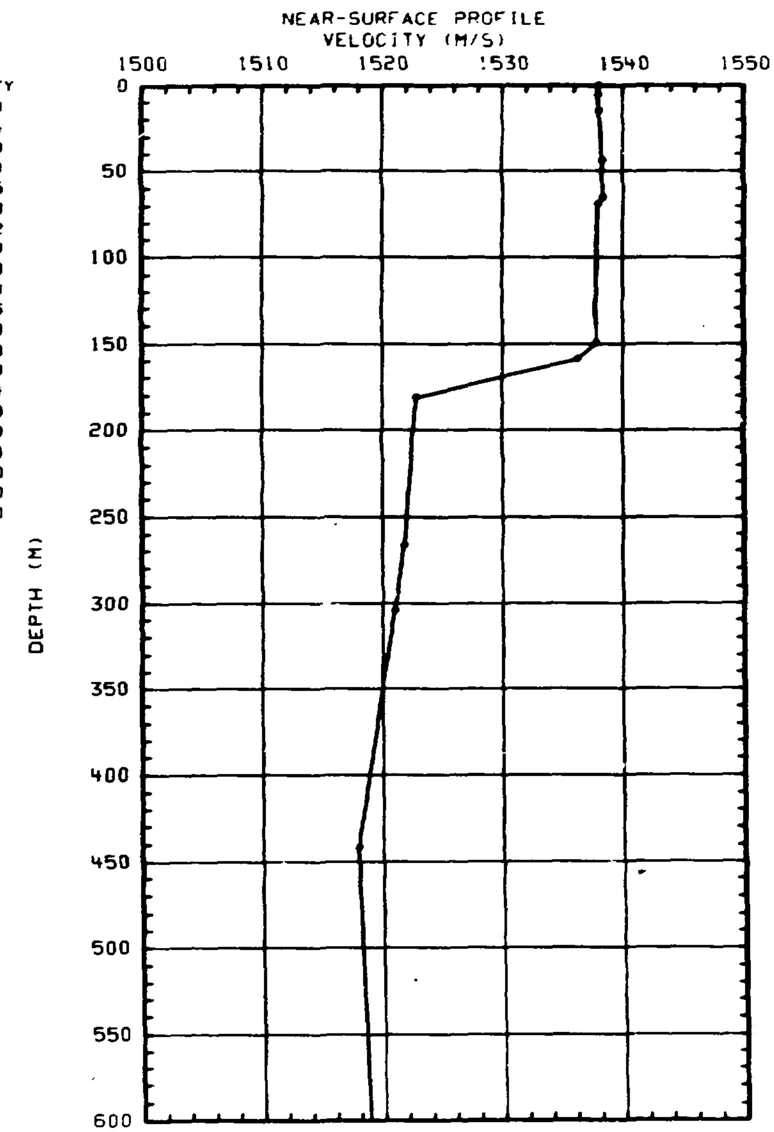


CONFIDENTIAL

(U) Figure IIIF-3. JOAST Station 3 Sound Speed Profile

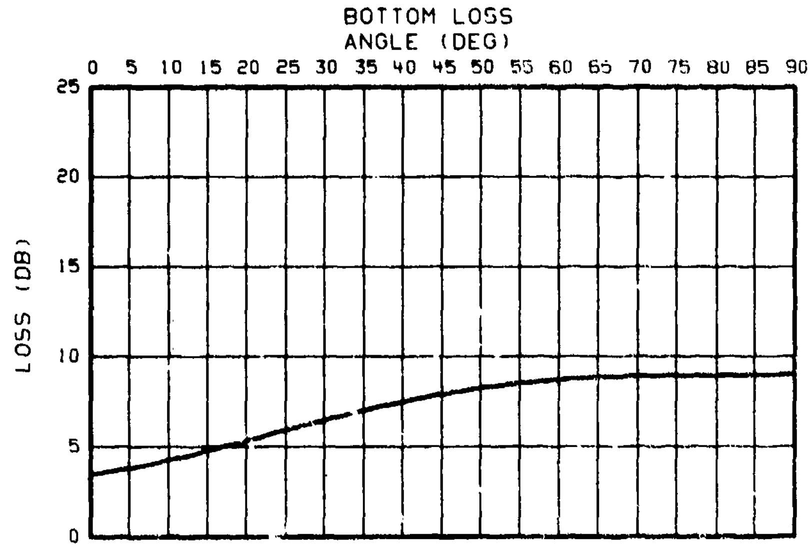


DEPTH	VELOCITY
0.0	1537.90
6.1	1537.94
15.5	1538.00
44.2	1538.30
65.5	1538.25
68.9	1537.90
149.6	1537.72
159.4	1536.20
161.3	1522.80
267.0	1521.80
304.8	1520.96
442.3	1517.90
616.0	1518.80
914.7	1522.50
1225.0	1526.74
1534.1	1532.20
1832.8	1537.10
2144.3	1542.60
2439.9	1547.40
2475.3	1548.70
2743.2	1553.30



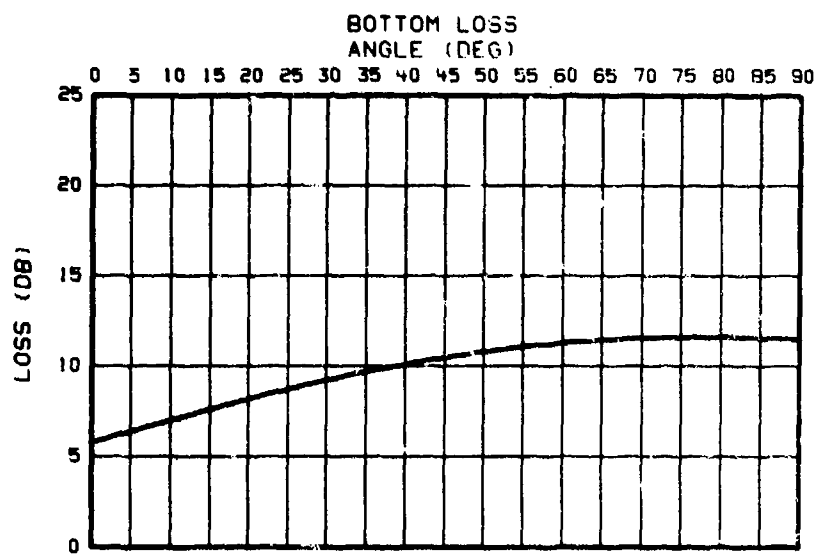
CONFIDENTIAL

(U) Figure IIIF-4. JOAST Station 5 Sound Speed Profile



CONFIDENTIAL

(C) Figure IIIF-5. Bottom Loss Versus Grazing Angle for JOAST Stations 1 and 2, FNOC Type 2, Frequency = 3.7 Kilohertz



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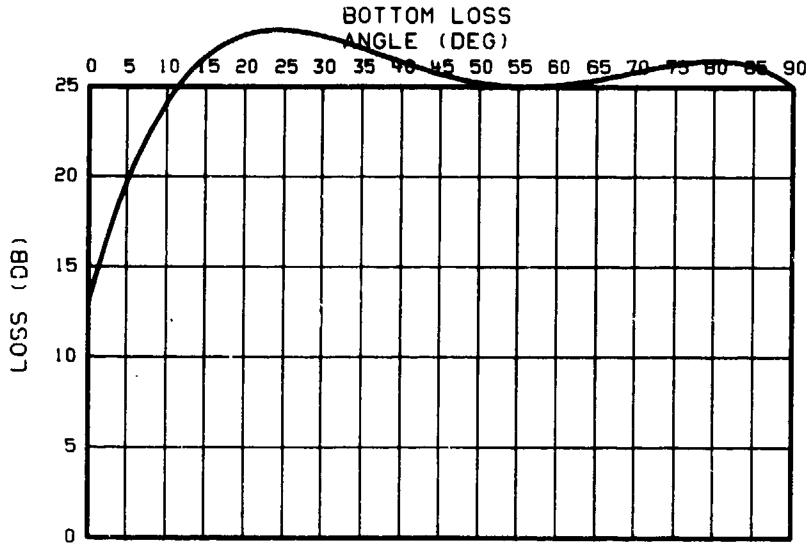
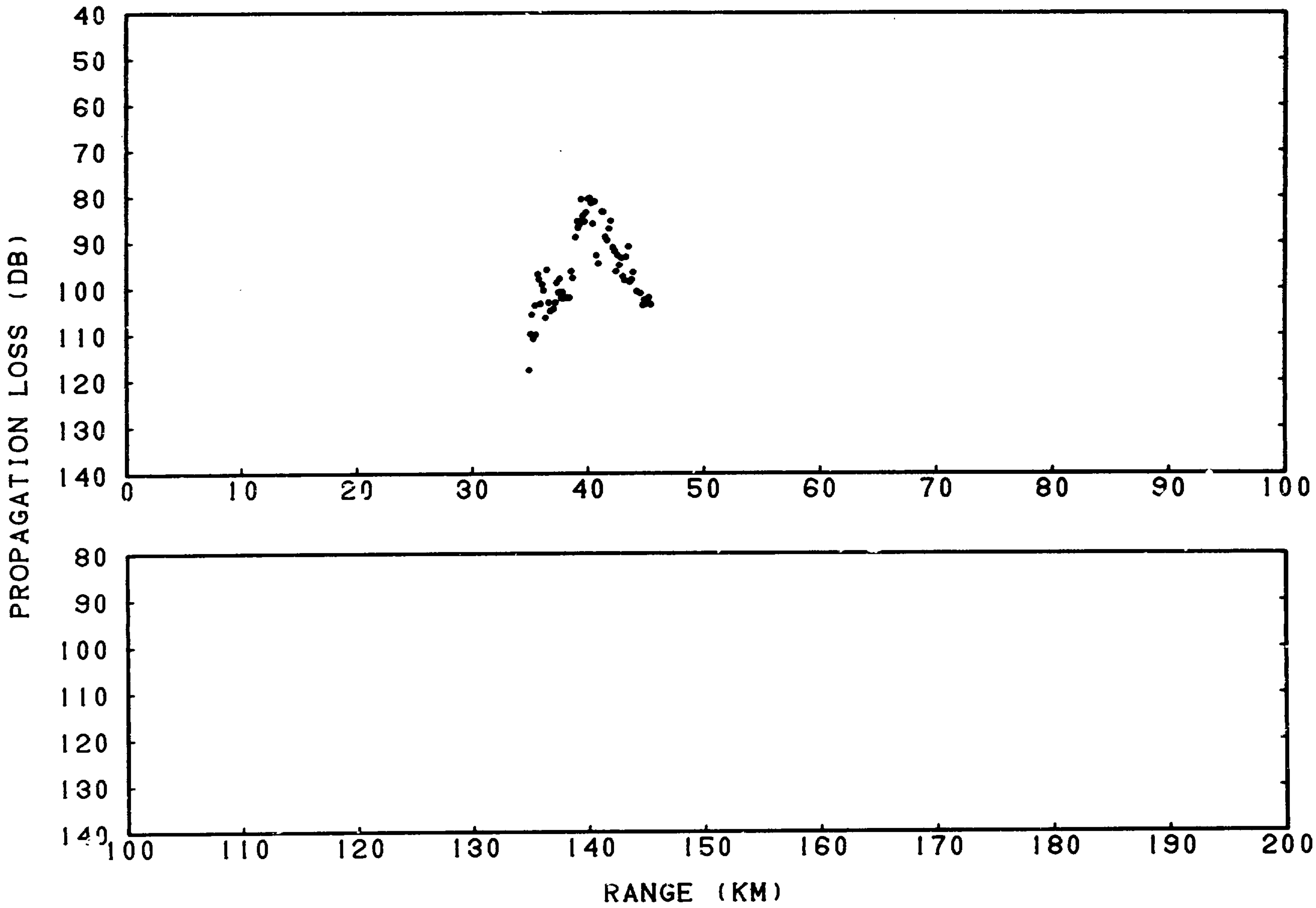
(C) Figure IIIF-6. Bottom Loss Versus Grazing Angle for JOAST Station 3, FNOC Type 3, Frequency = 3700 Hertz



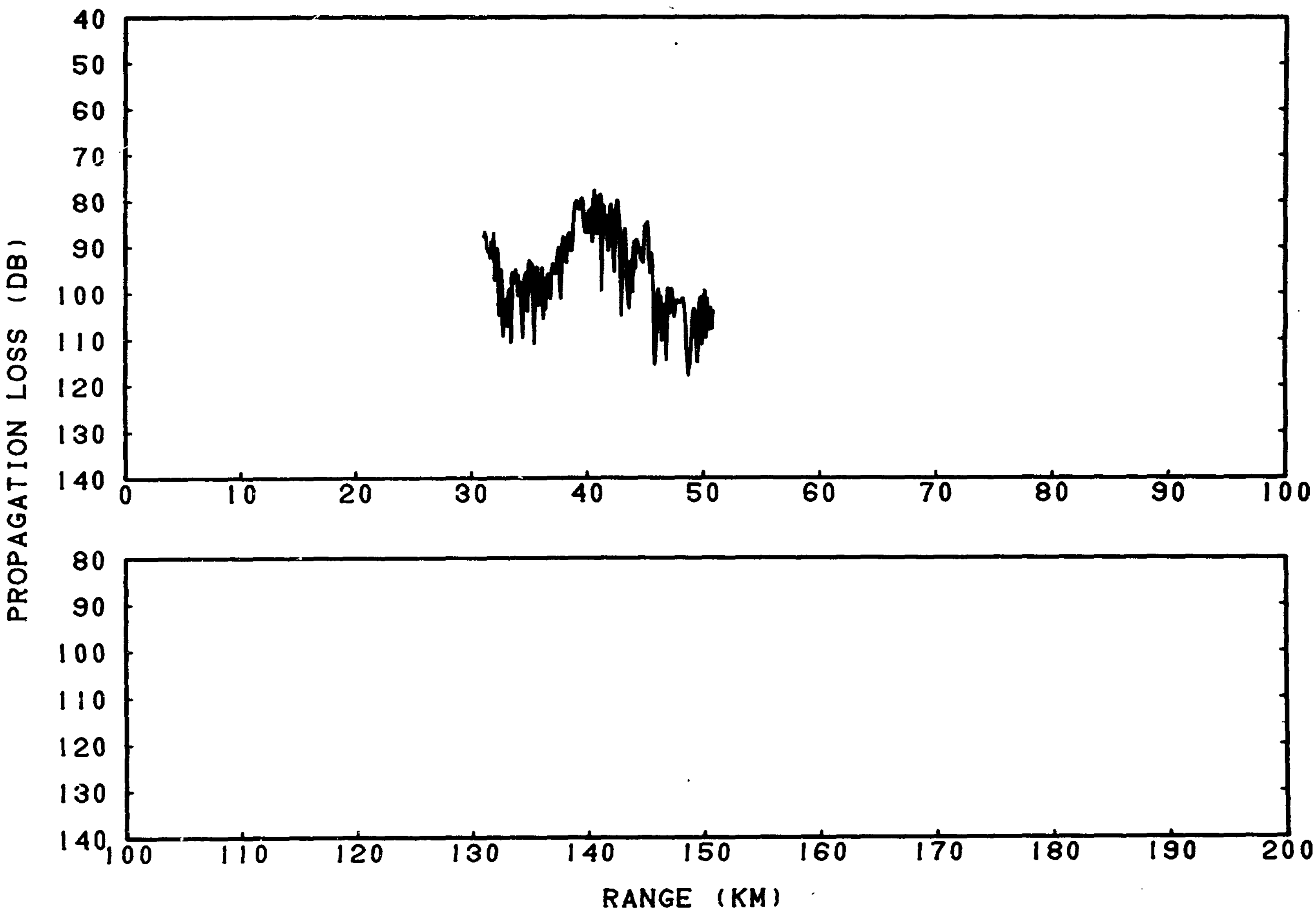
CONFIDENTIAL

(C) Figure IIIF-7. Bottom Loss Versus Grazing Angle for JOAST Station 5, FNOC Type 8, Frequency = 3700 Hertz



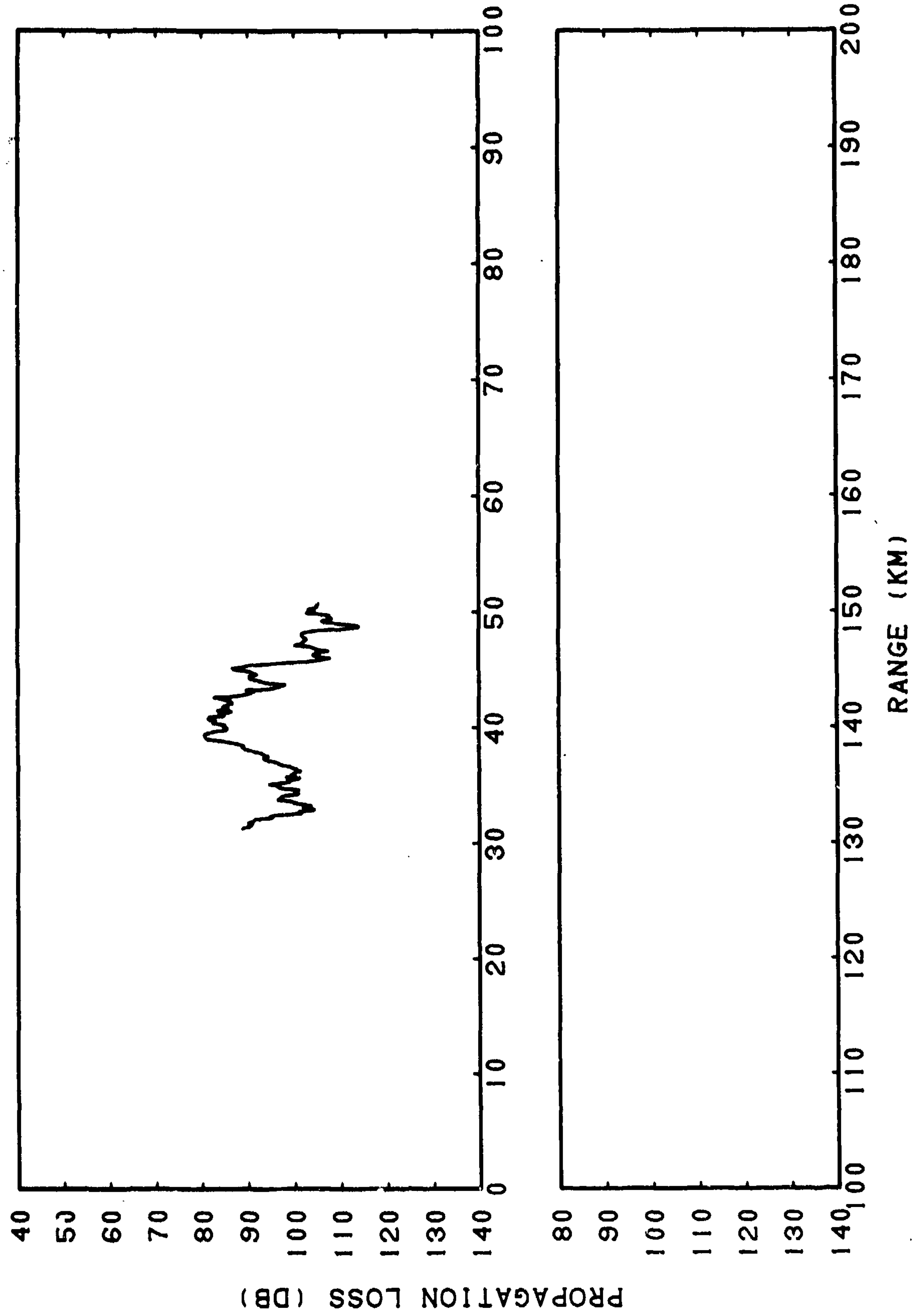
CONFIDENTIAL

(C) Figure IIIF-8a. RAYMODE Incoherent Station 1 Run 43, Source Depth = 20 Feet, Receiver Depth = 60 Feet



CONFIDENTIAL

(C) Figure IIIF-8b. RAYMODE Coherent Station 1 Run 43, Source Depth = 20 Feet, Receiver Depth = 60 Feet



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(C) Figure IIIF-8c. RAYMODE Coherent Station 1 Run 43, Source Depth = 20 Feet, Receiver Depth = 60 Feet, Sliding Averages of 5 Points (0.39 Kilometer)

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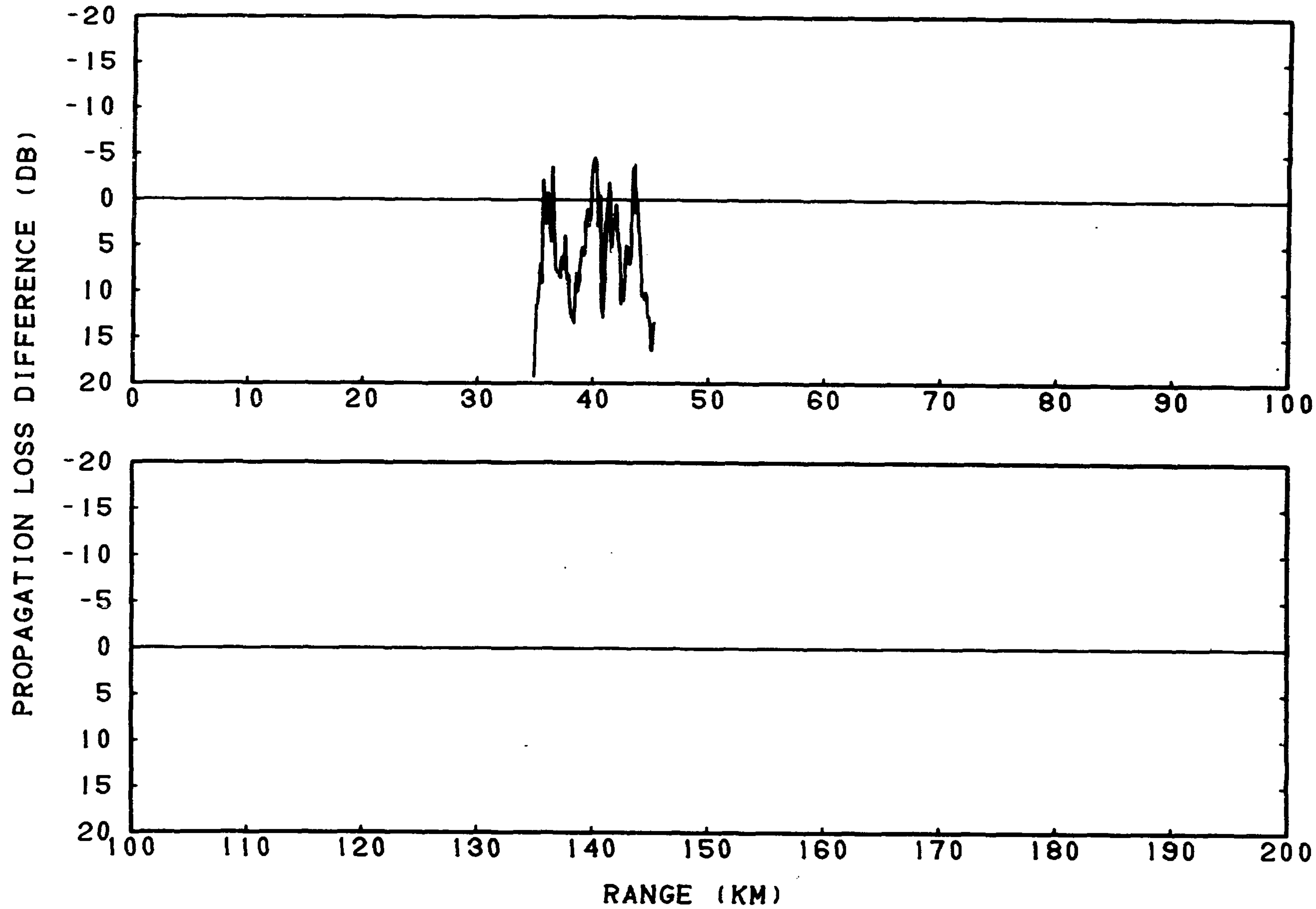

CONFIDENTIAL

(C) Figure IIIF-8d. Smoothed RAYMODE Coherent Station 1 Run 43, Source Depth = 20 Feet, Receiver Depth = 60 Feet, Subtracted from Station 1 Run 43, Source Depth = 20 Feet, Receiver Depth = 60 Feet

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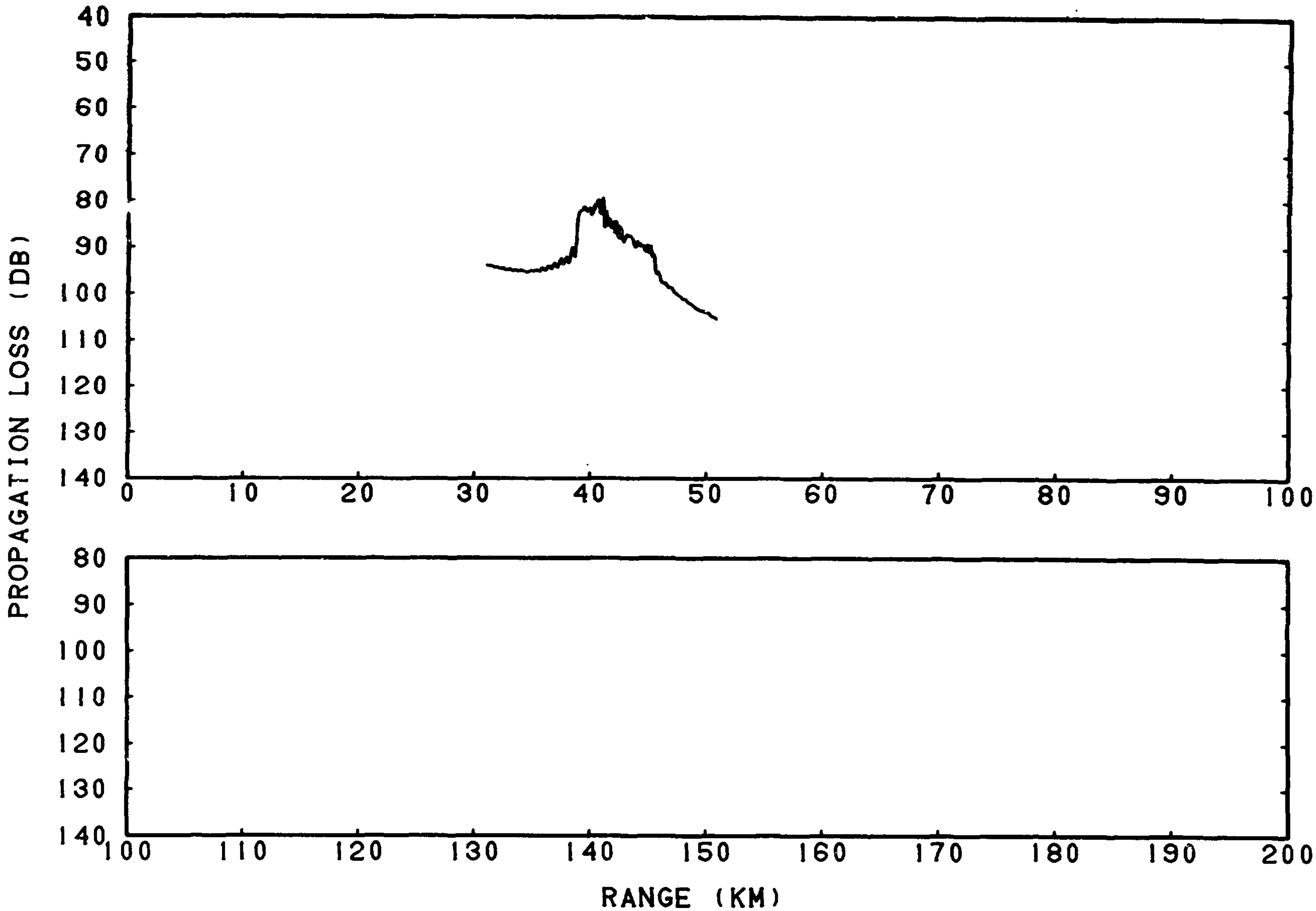

CONFIDENTIAL

(C) Figure IIIF-8e. RAYMODE Incoherent Station 1 Run 43, Source Depth = 20 Feet, Receiver Depth = 60 Feet, Subtracted from Station 1 Run 43, Source Depth = 20 Feet, Receiver Depth = 60 Feet

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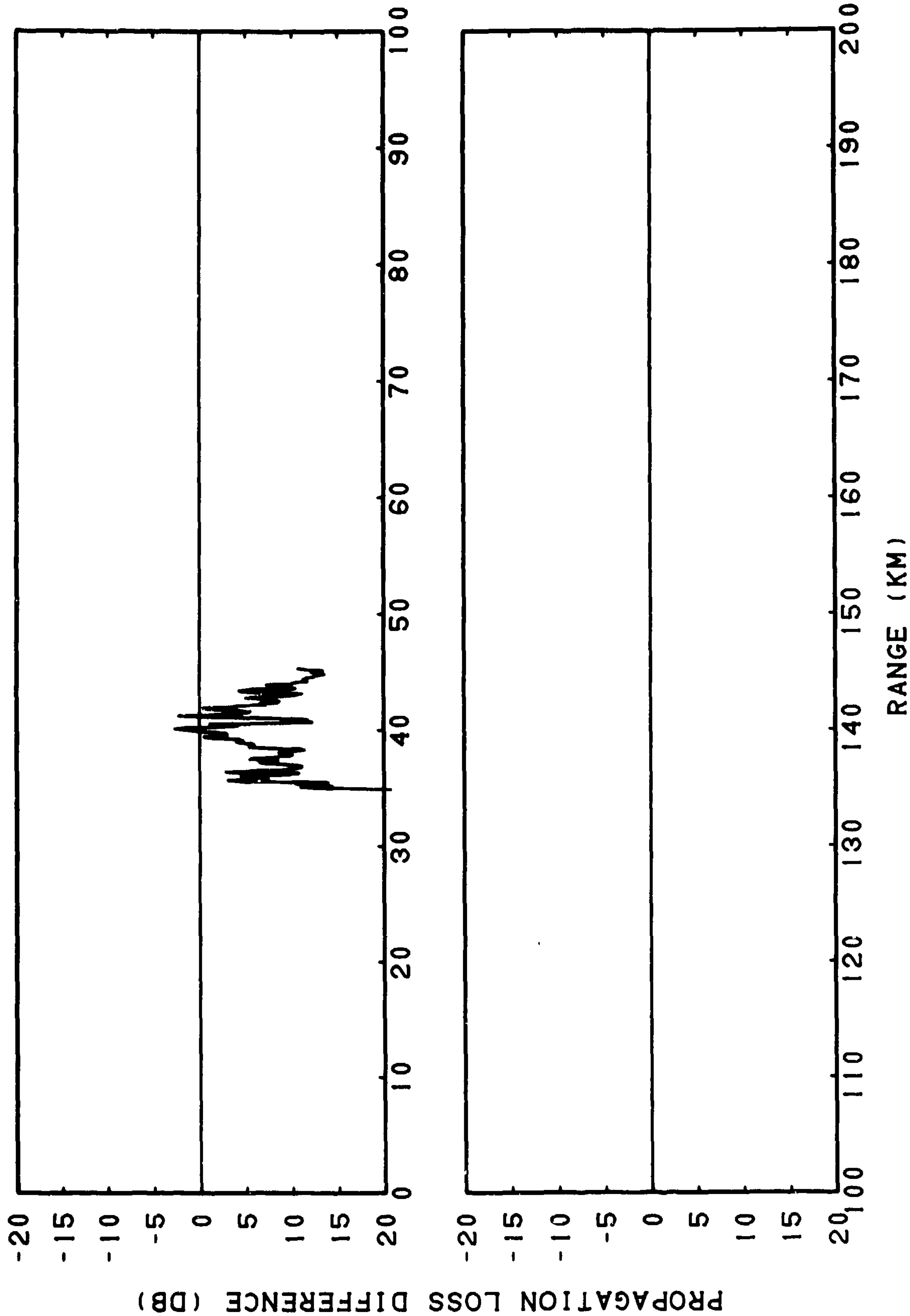
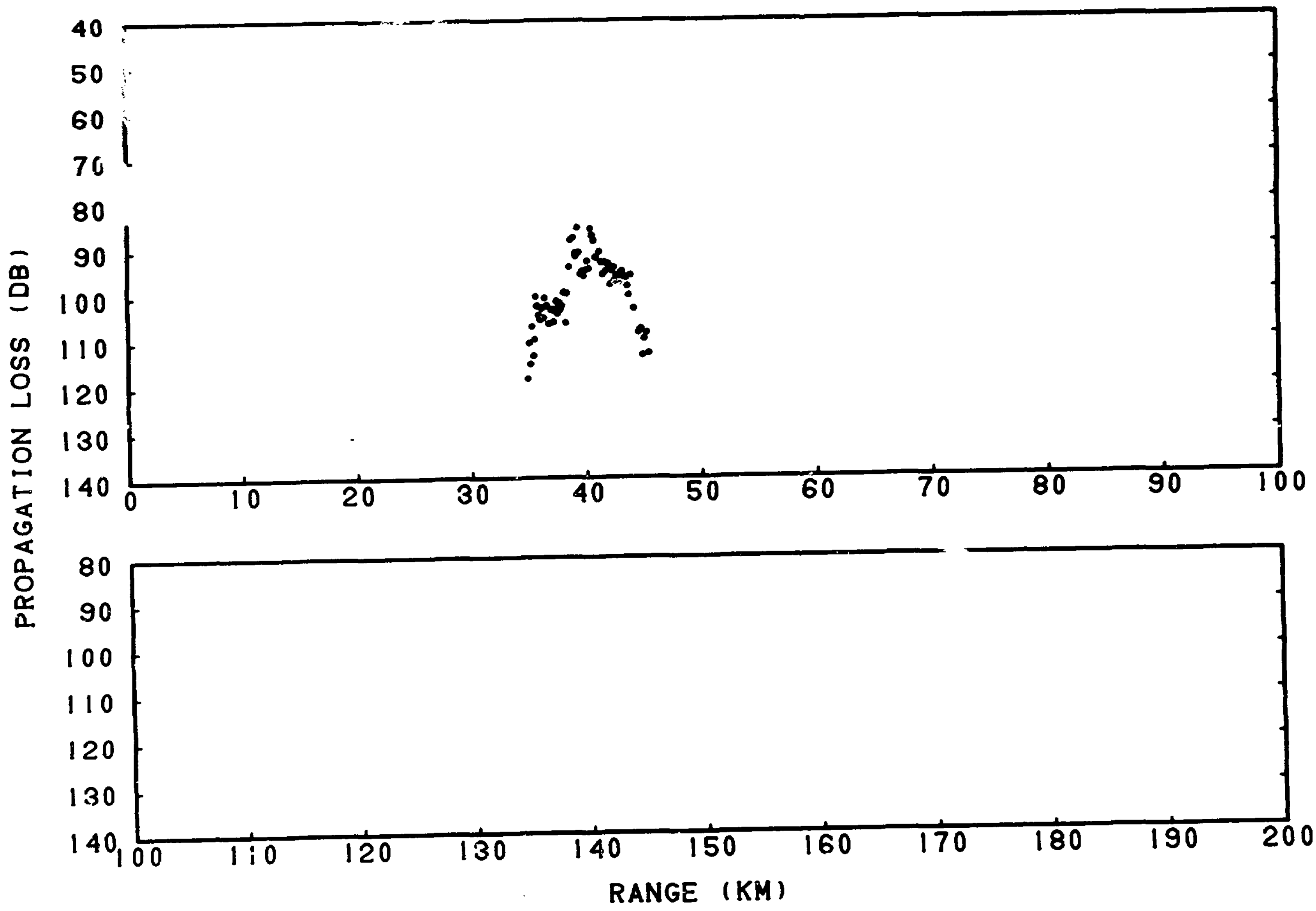


CONFIDENTIAL

(C) Figure IIIF-8f. Station 1 Run 43, Source Depth = 20 Feet, Receiver Depth = 60 Feet

CONFIDENTIAL



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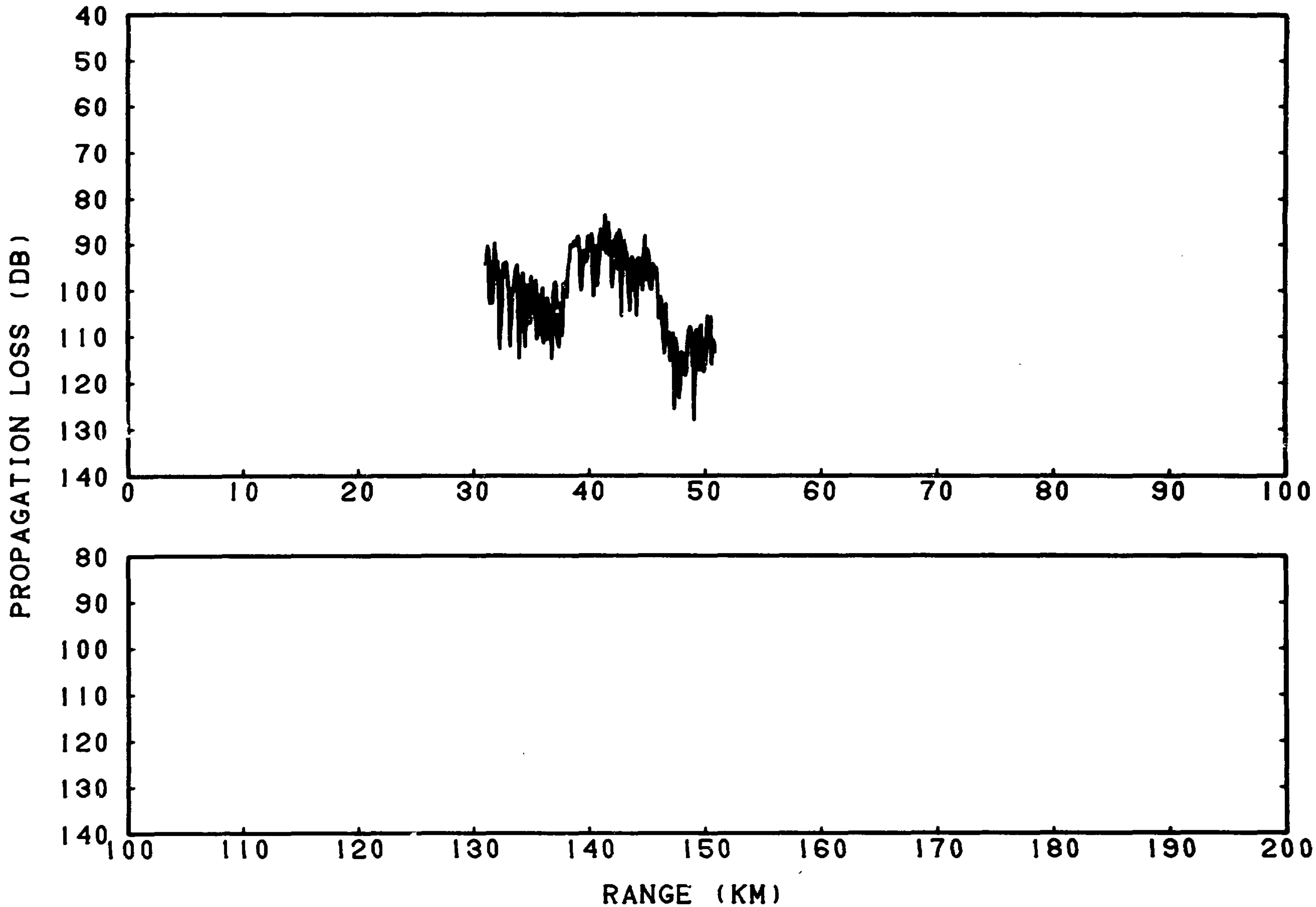
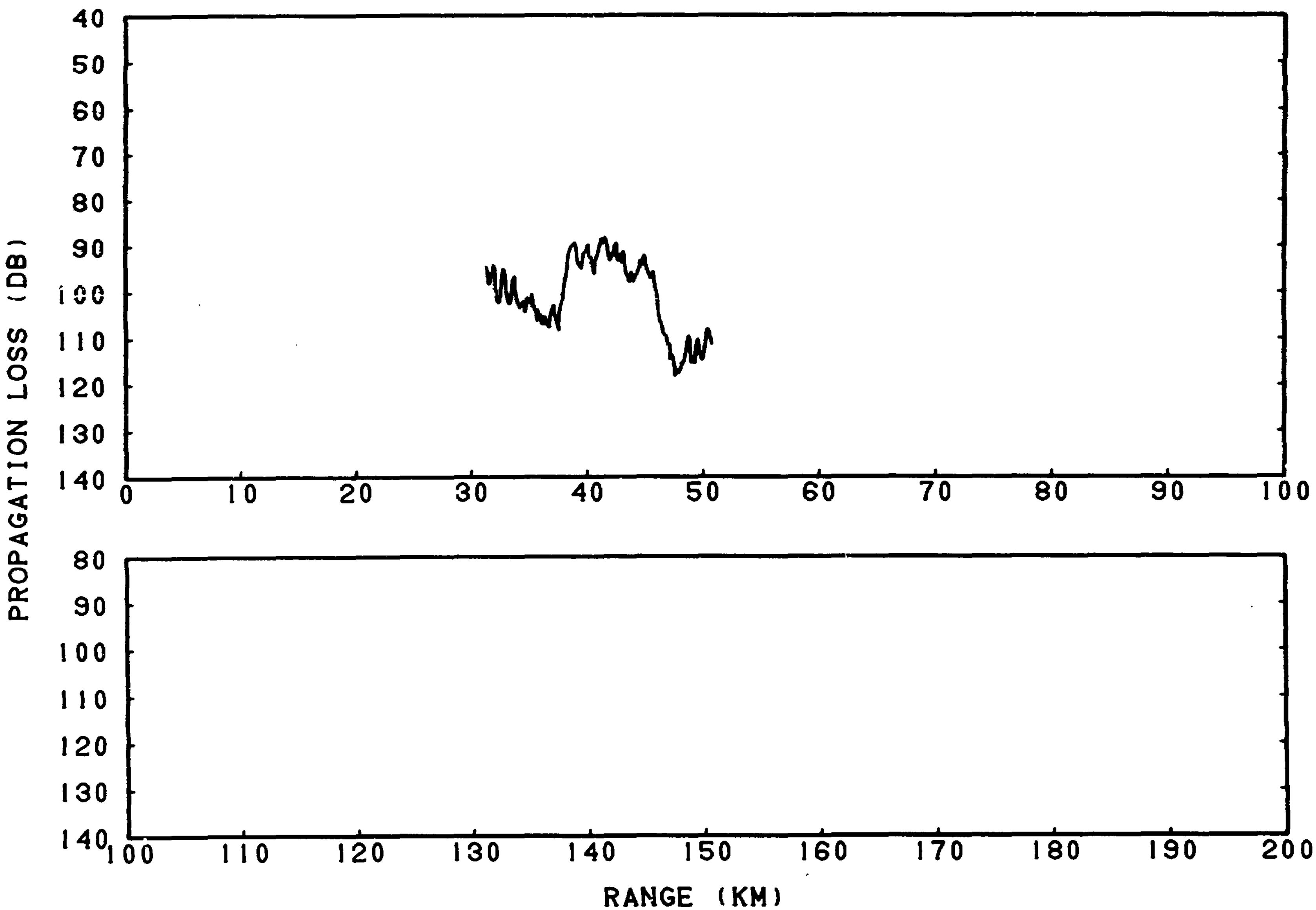
(C) Figure IIIF-9a. Station 1 Run 43, Source Depth = 20 Feet, Receiver Depth = 260 Feet



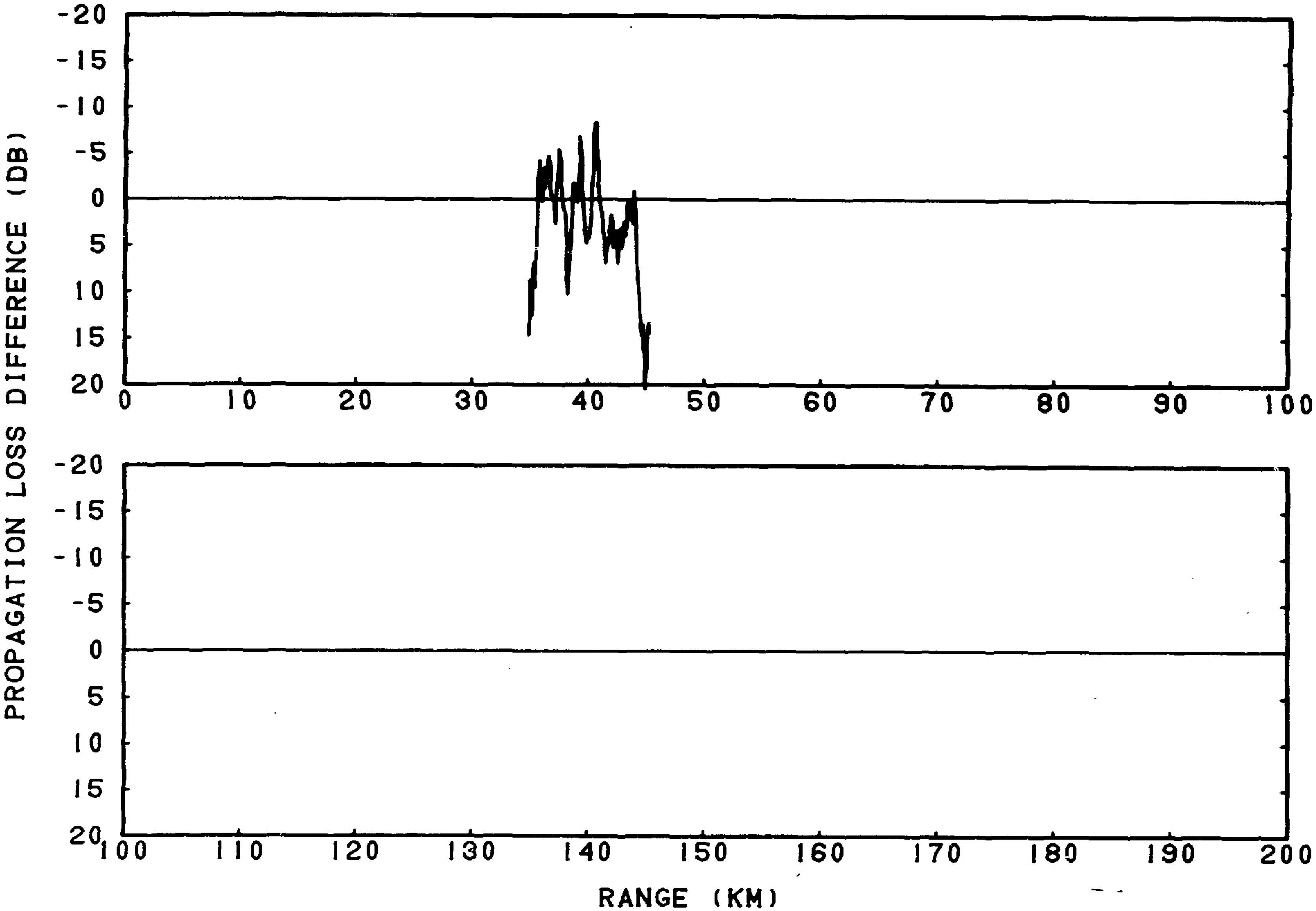
CONFIDENTIAL

(C) Figure IIIF-9b. RAYMODE Coherent Station 1 Run 43, Source Depth = 20 Feet, Receiver Depth = 260 Feet



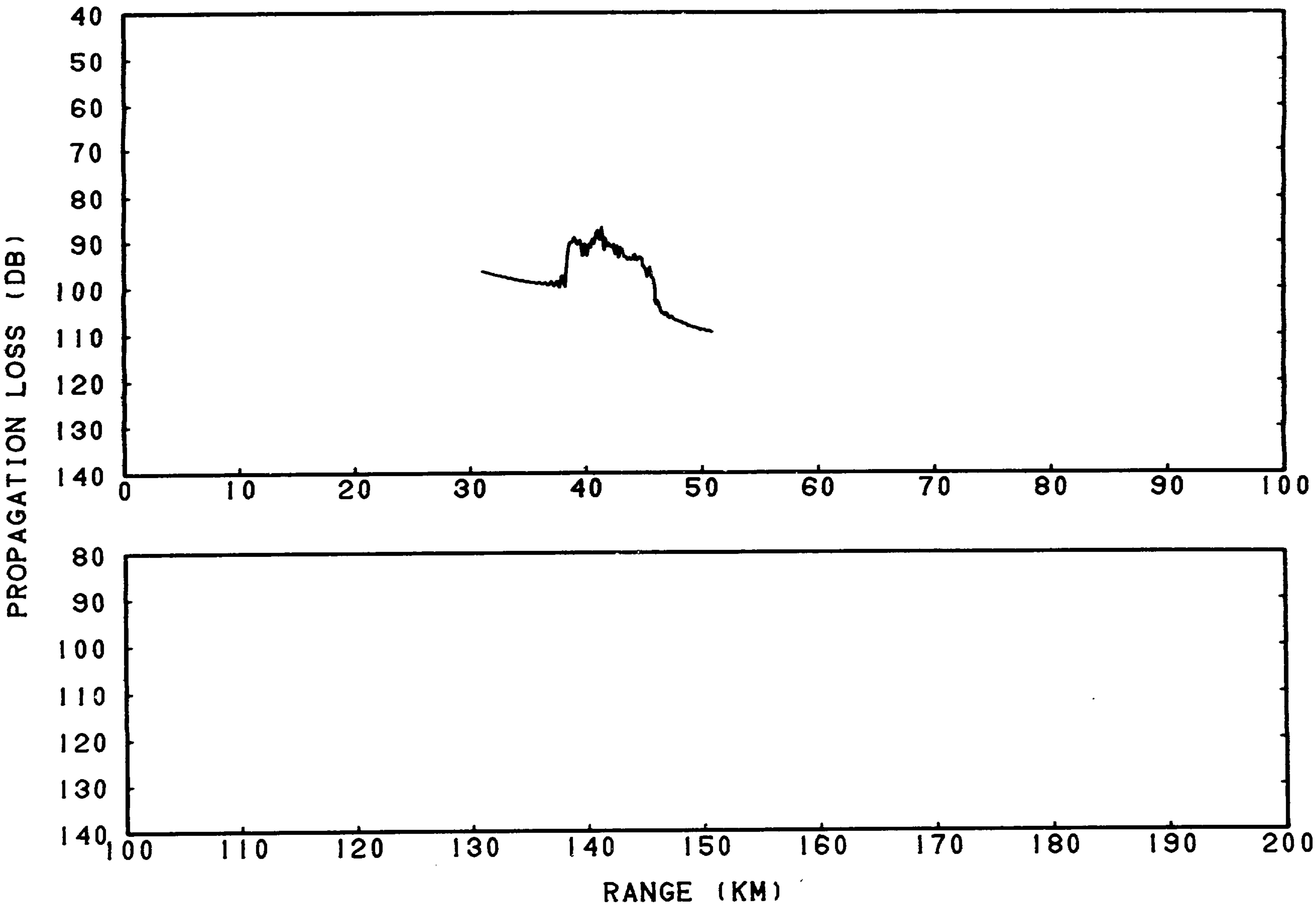
CONFIDENTIAL

(C) Figure IIIF-9c. RAYMODE Coherent Station ' Run 43, Source Depth = 20 Feet, Receiver Depth = 260 Feet, Sliding Averages of 5 Points (0.39 Kilometer)



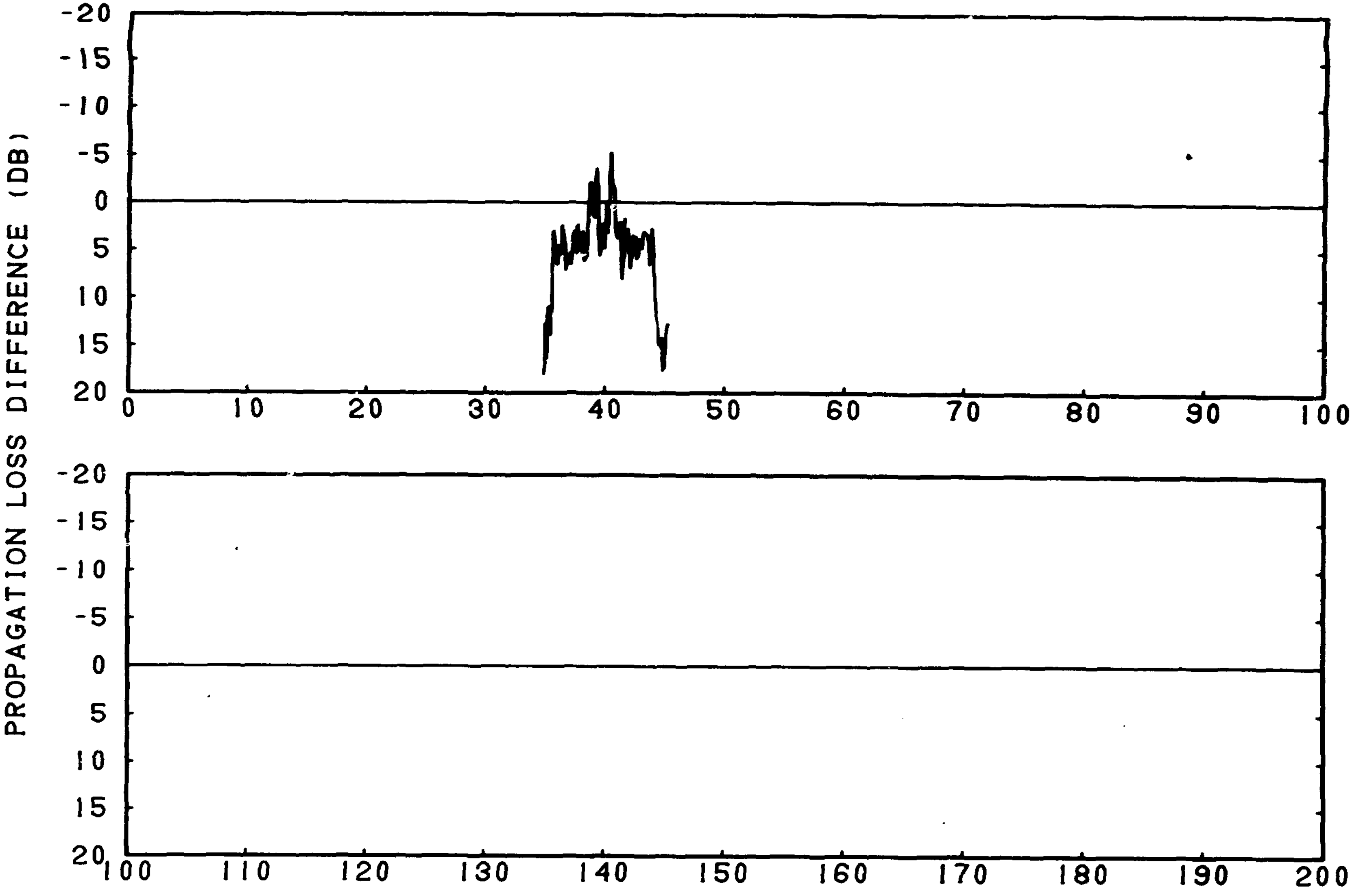
CONFIDENTIAL

(C) Figure IIIF-9d. Smoothed RAYMODE Coherent Station 1 Run 43, Source Depth = 20 Feet, Receiver Depth 260 Feet, Subtracted from Station 1 Run 43, Source Depth = 20 Feet, Receiver Depth = 260 Feet



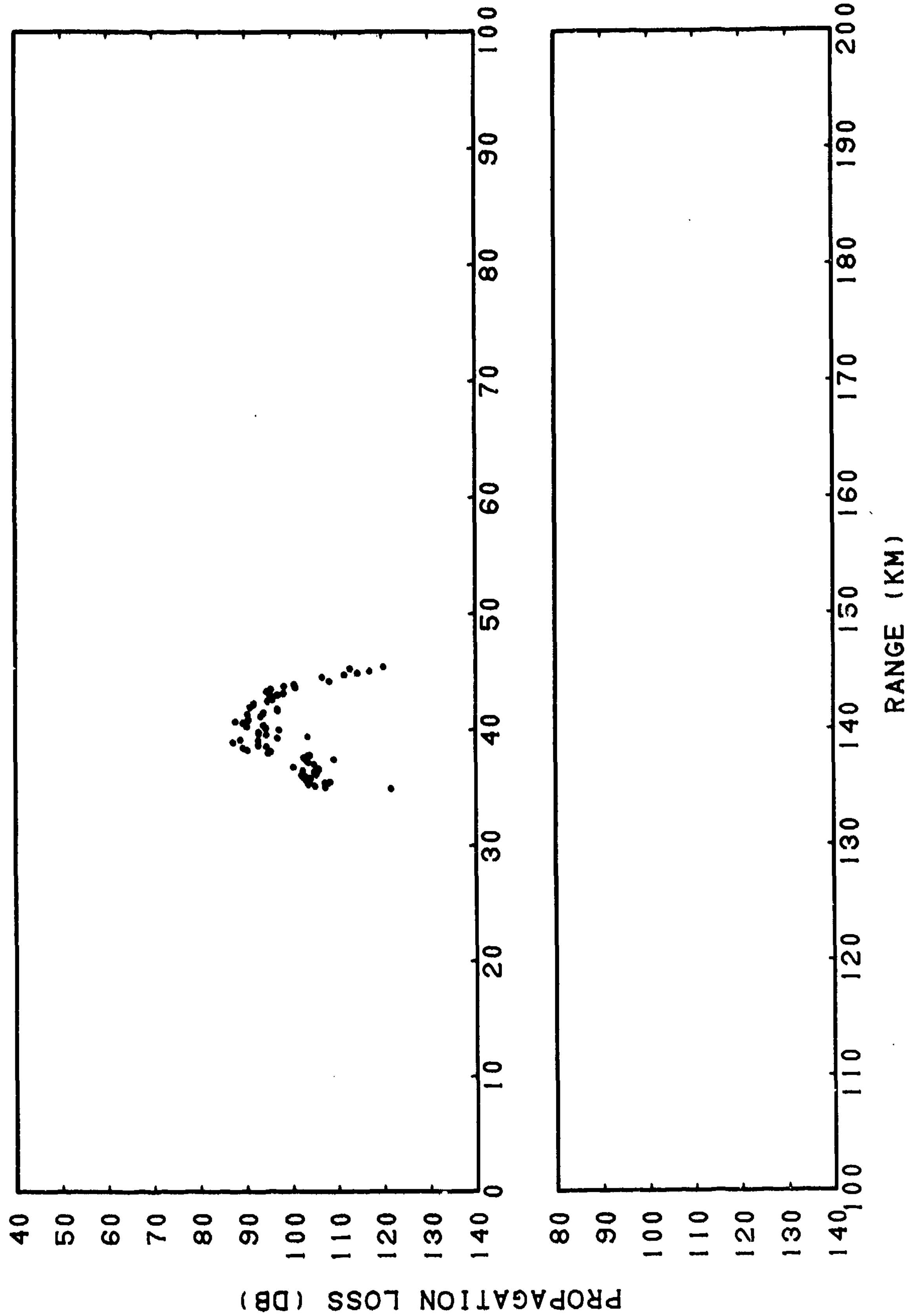
CONFIDENTIAL

(C) Figure IIIF-9e. RAYMODE Incoherent Station 1 Run 43, Source Depth = 20 Feet, Receiver Depth = 260 Feet



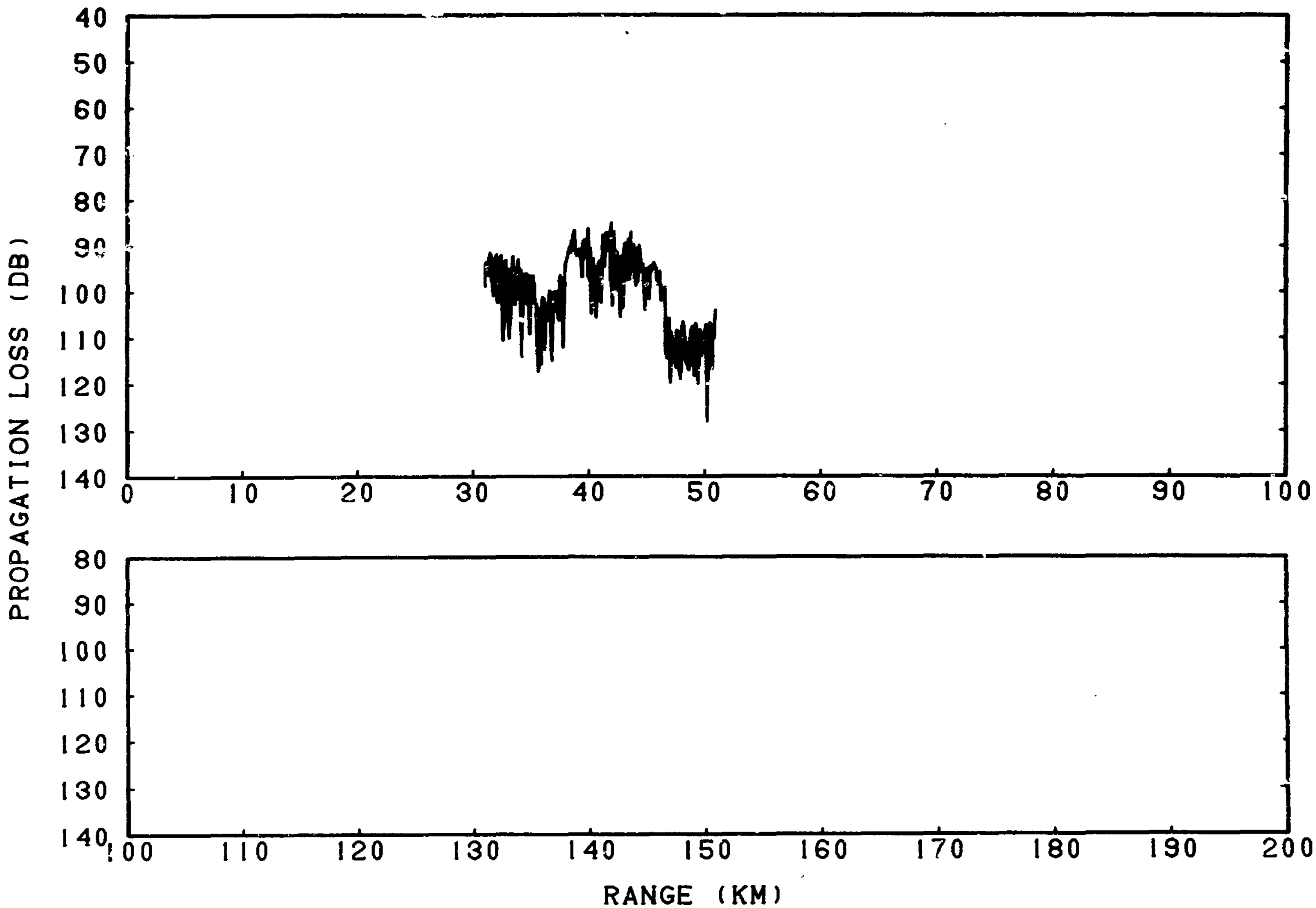
CONFIDENTIAL

(C) Figure IIIF-9f. RAYMODE Incoherent Station 1 Run 43, Source Depth = 20 Feet, Receiver Depth = 260 Feet, Subtracted from Station 1 Run 43, Source Depth = 20 Feet, Receiver Depth = 260 Feet



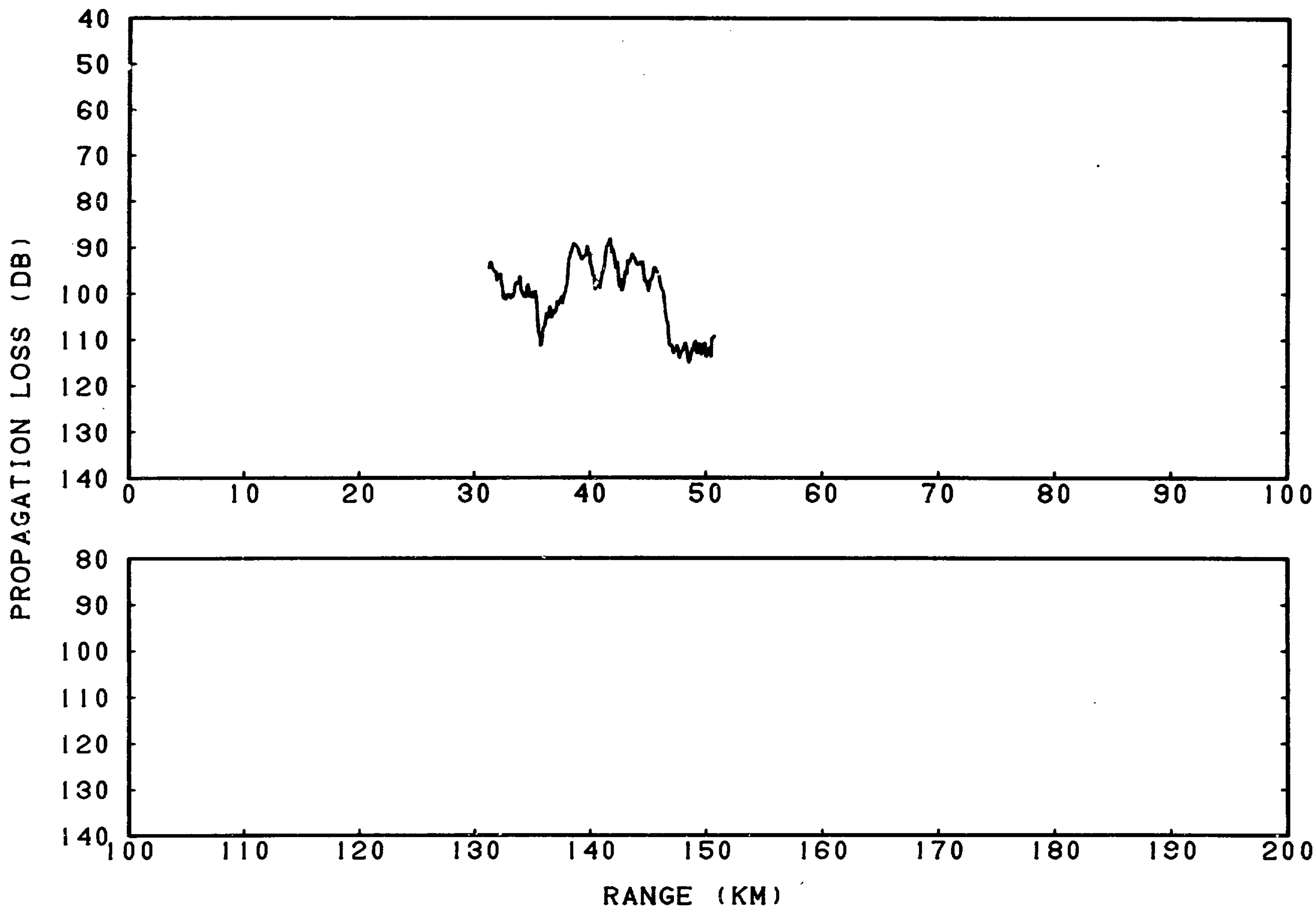
CONFIDENTIAL

(C) Figure IIIF-10a. Station 1 Run 43, Source Depth = 20 Feet, Receiver Depth = 535 Feet



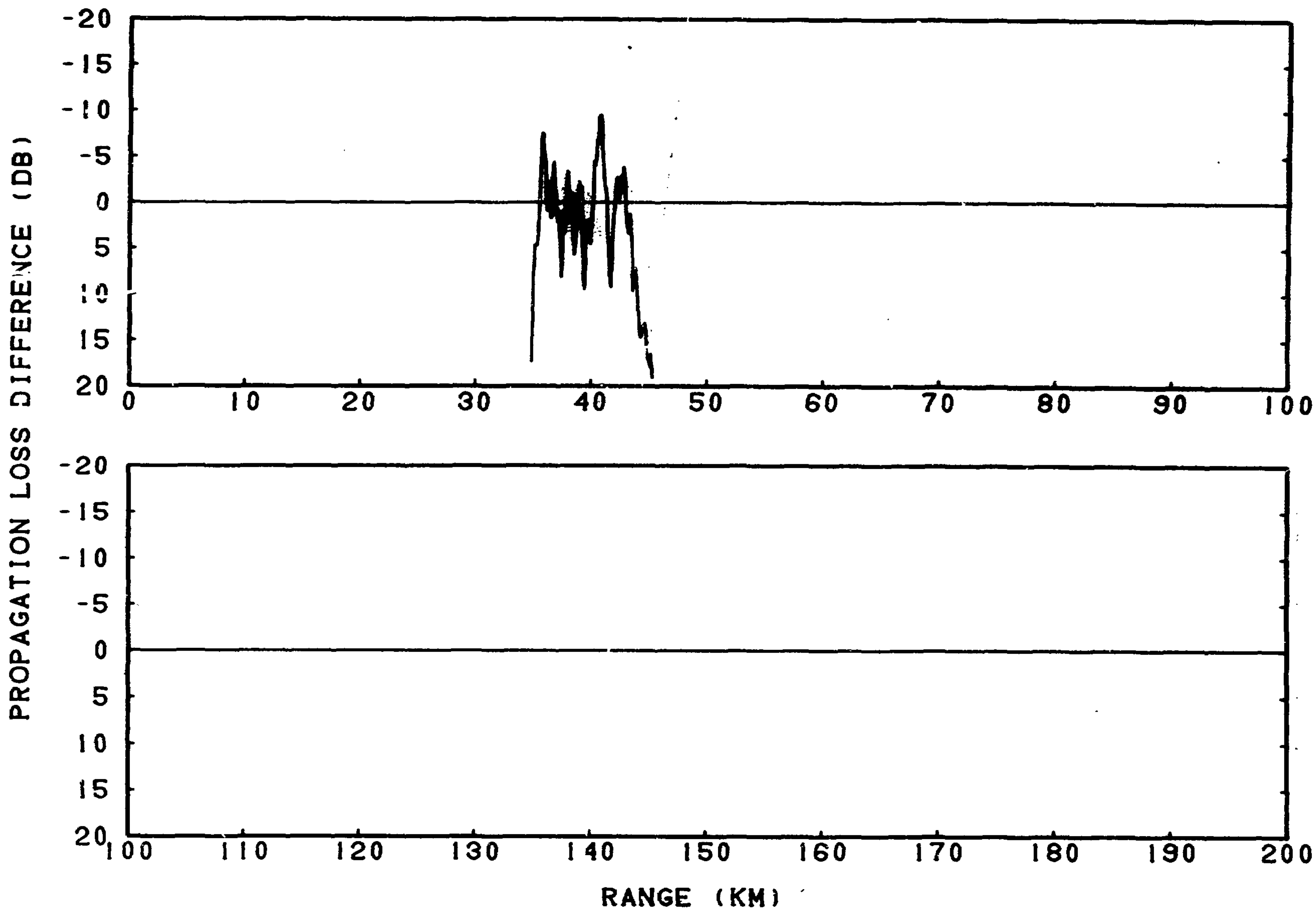
CONFIDENTIAL

(C) Figure IIIF-10b. RAYMODE Coherent Station 1 Run 43, Source Depth = 20 Feet, Receiver Depth = 535 Feet



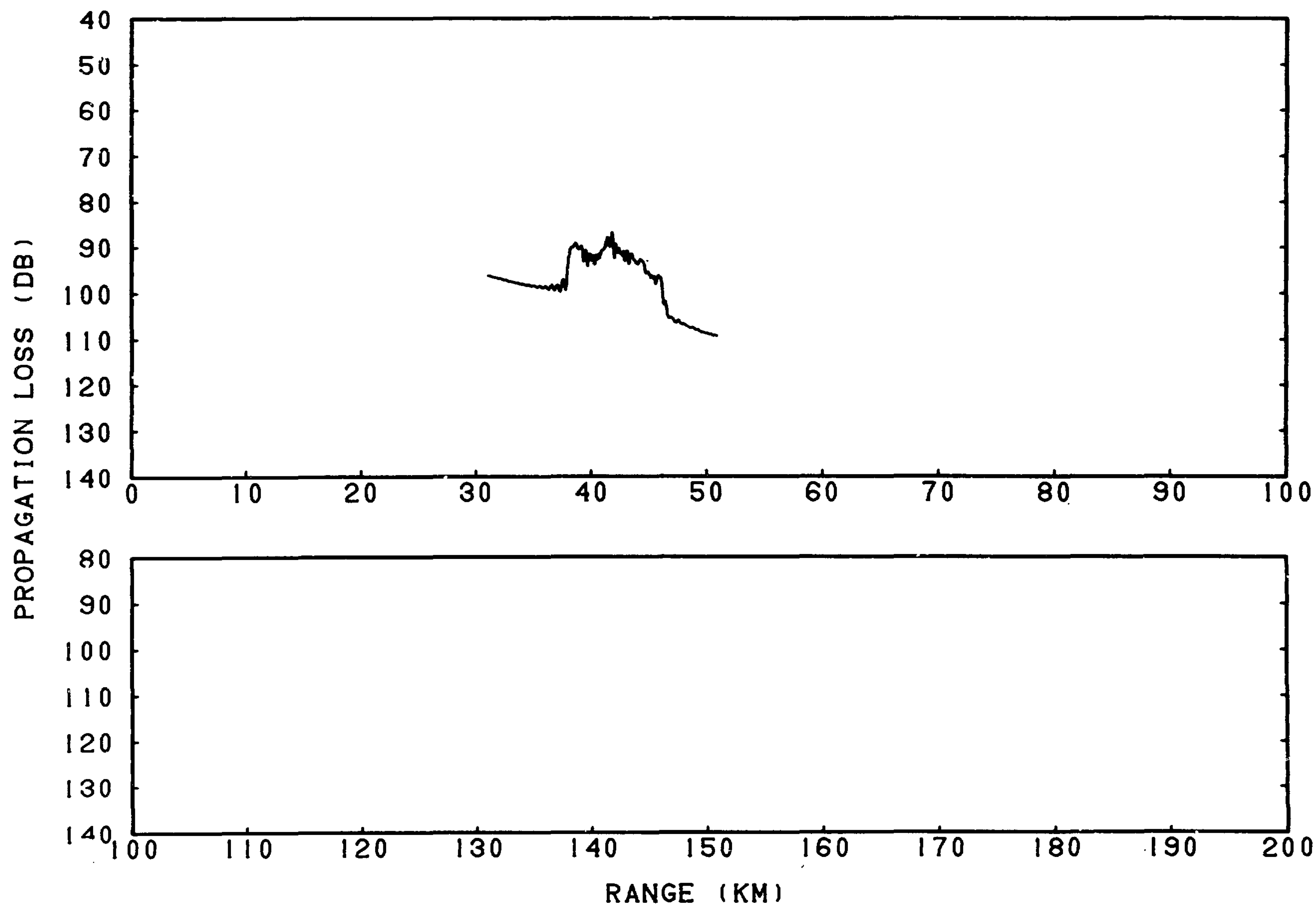
CONFIDENTIAL

(C) Figure IIIF-10c. RAYMODE Coherent Station 1 Run 43, Source Depth = 20 Feet, Receiver Depth = 535 Feet, Sliding Averages of 5 Points (0.39 Kilometer)



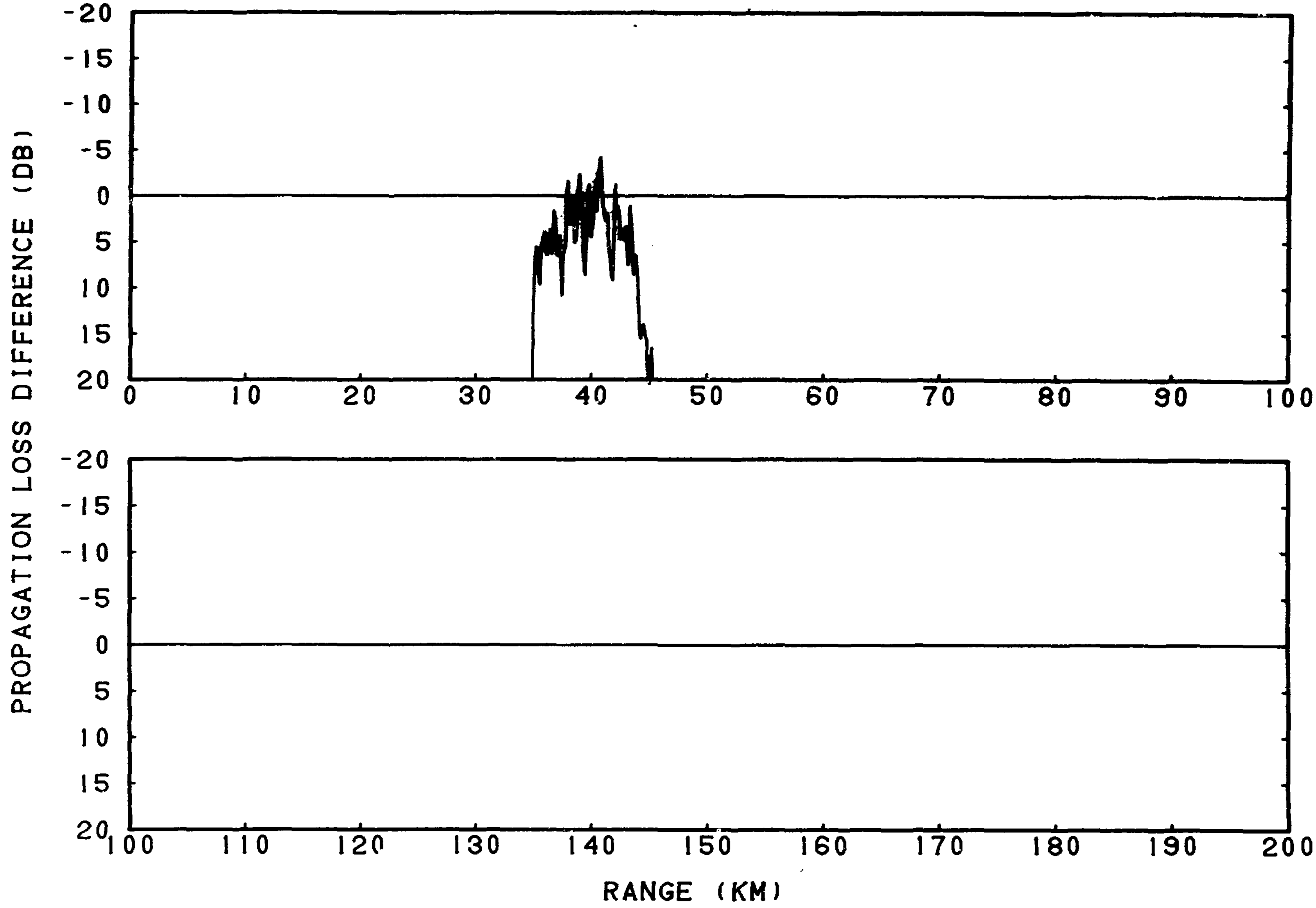
CONFIDENTIAL

(C) Figure IIIF-10d. Smoothed RAYMODE Coherent Station 1 Run 43, Source Depth = 20 Feet, Receiver Depth = 535 Feet, Subtracted from Station 1 Run 43, Source Depth = 20 Feet, Receiver Depth = 535 Feet



CONFIDENTIAL

(C) Figure IIIF-10e. RAYMODE Incoherent Station 1 Run 43, Source Depth = 20, Receiver Depth = 535 Feet



CONFIDENTIAL

(C) Figure IIIF-10f. RAYMODE Incoherent Station 1 Run 43, Source Depth = 20, Receiver Depth = 535 Feet, Subtracted from Station 1 Run 43, Source Depth = 20 Feet, Receiver Depth = 535 Feet

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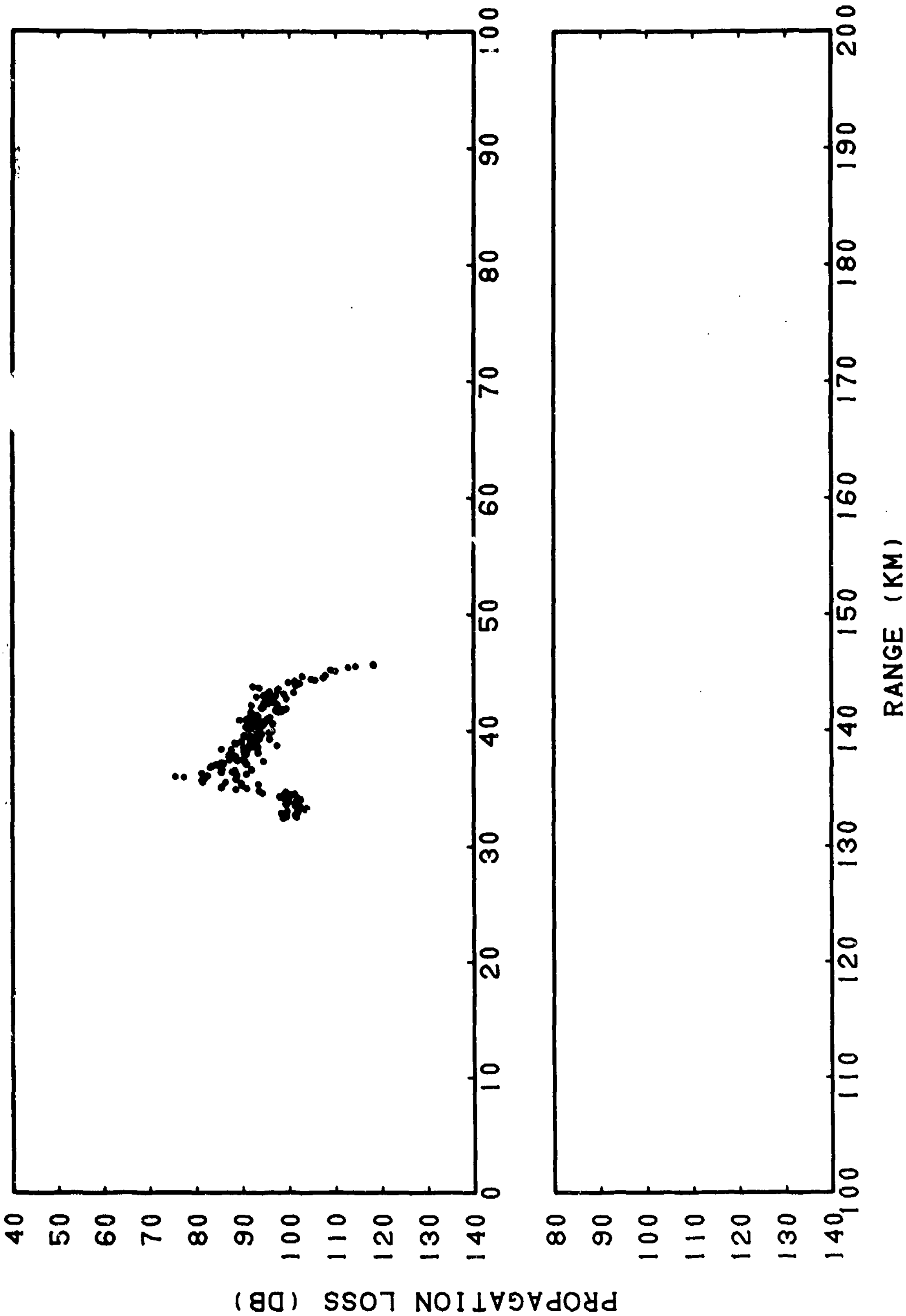
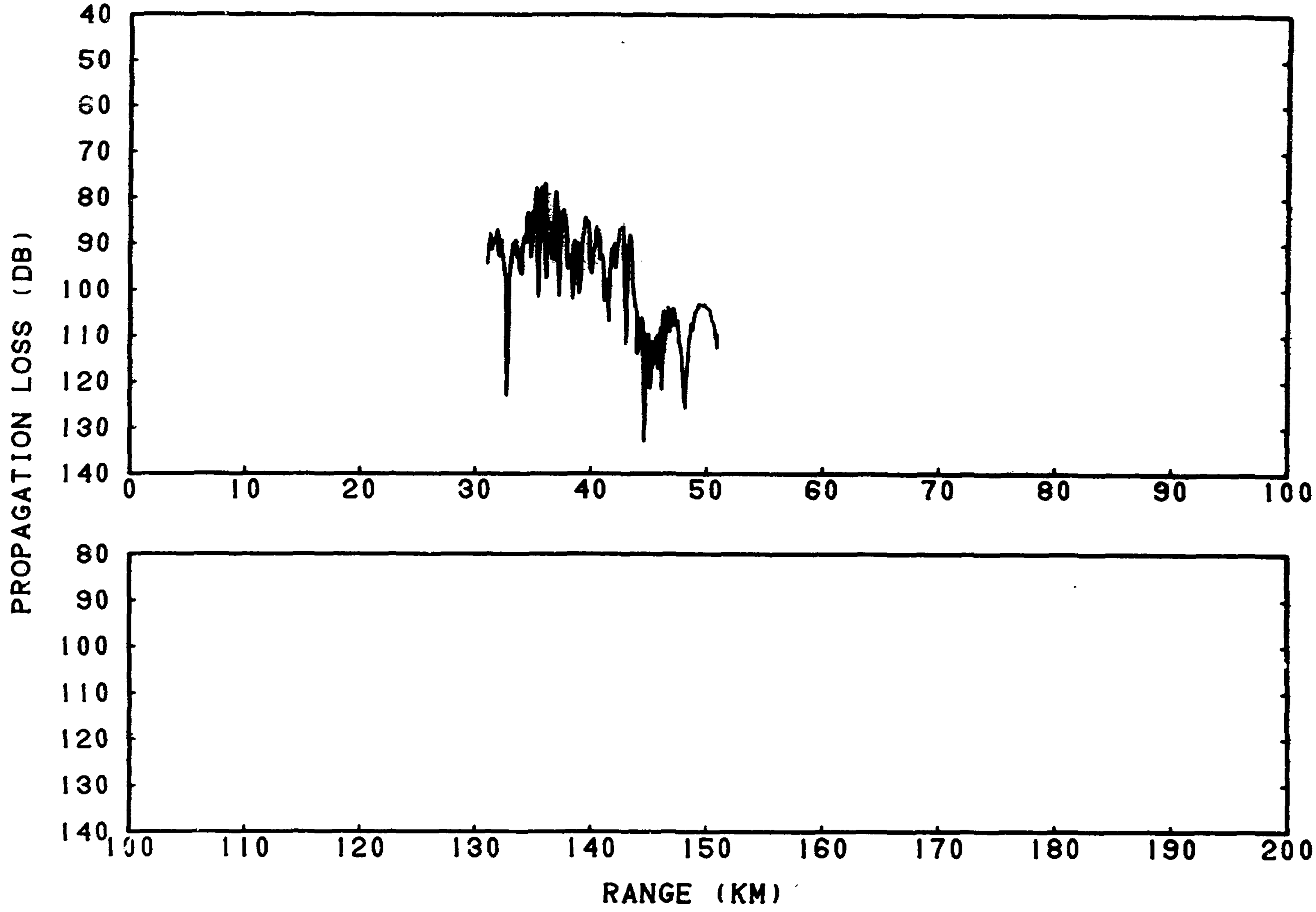


CONFIDENTIAL

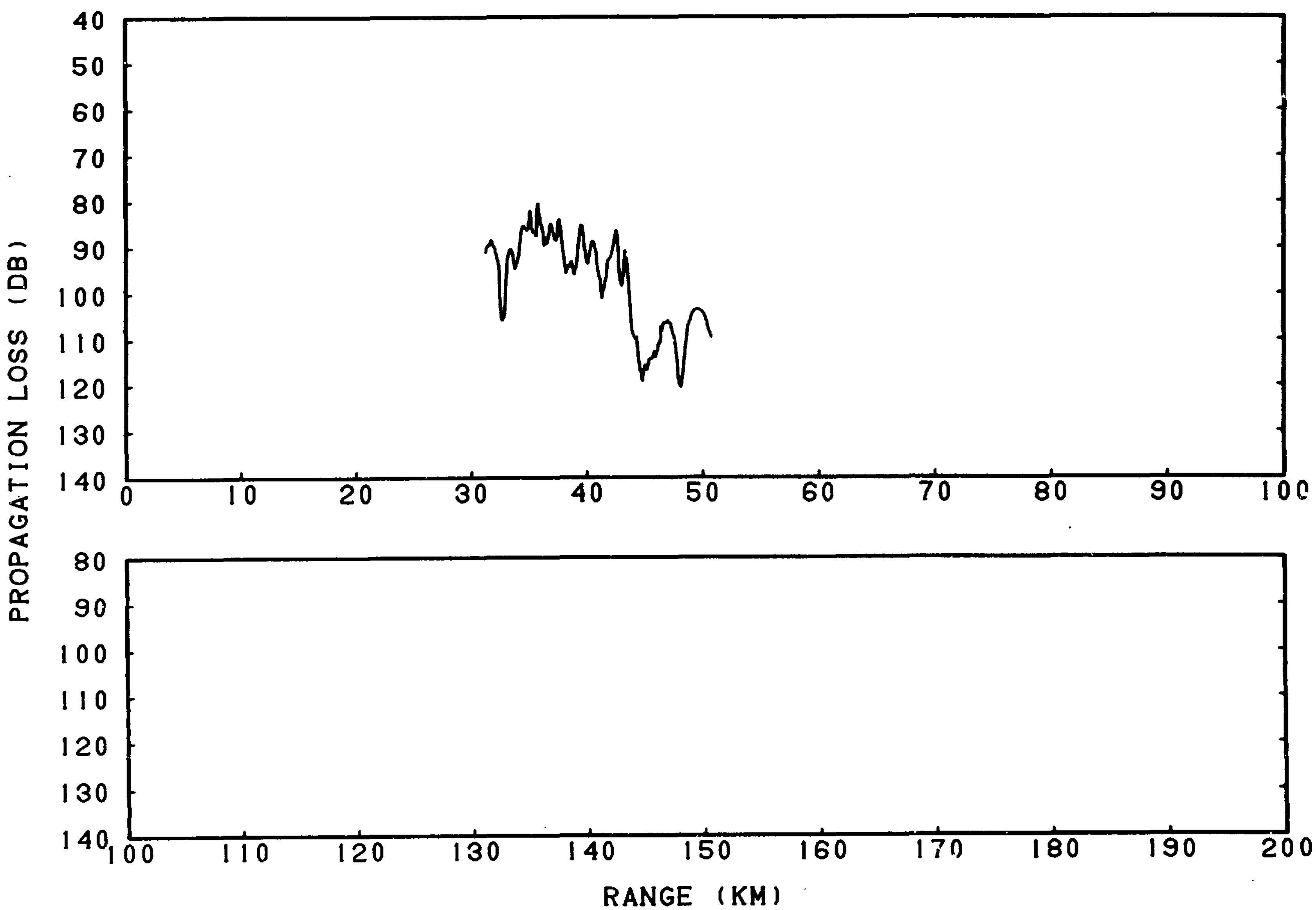
(C) Figure IIIF-11a. Station 2 Run 63, Source Depth = 20 Feet, Receiver Depth = 60 Feet

CONFIDENTIAL



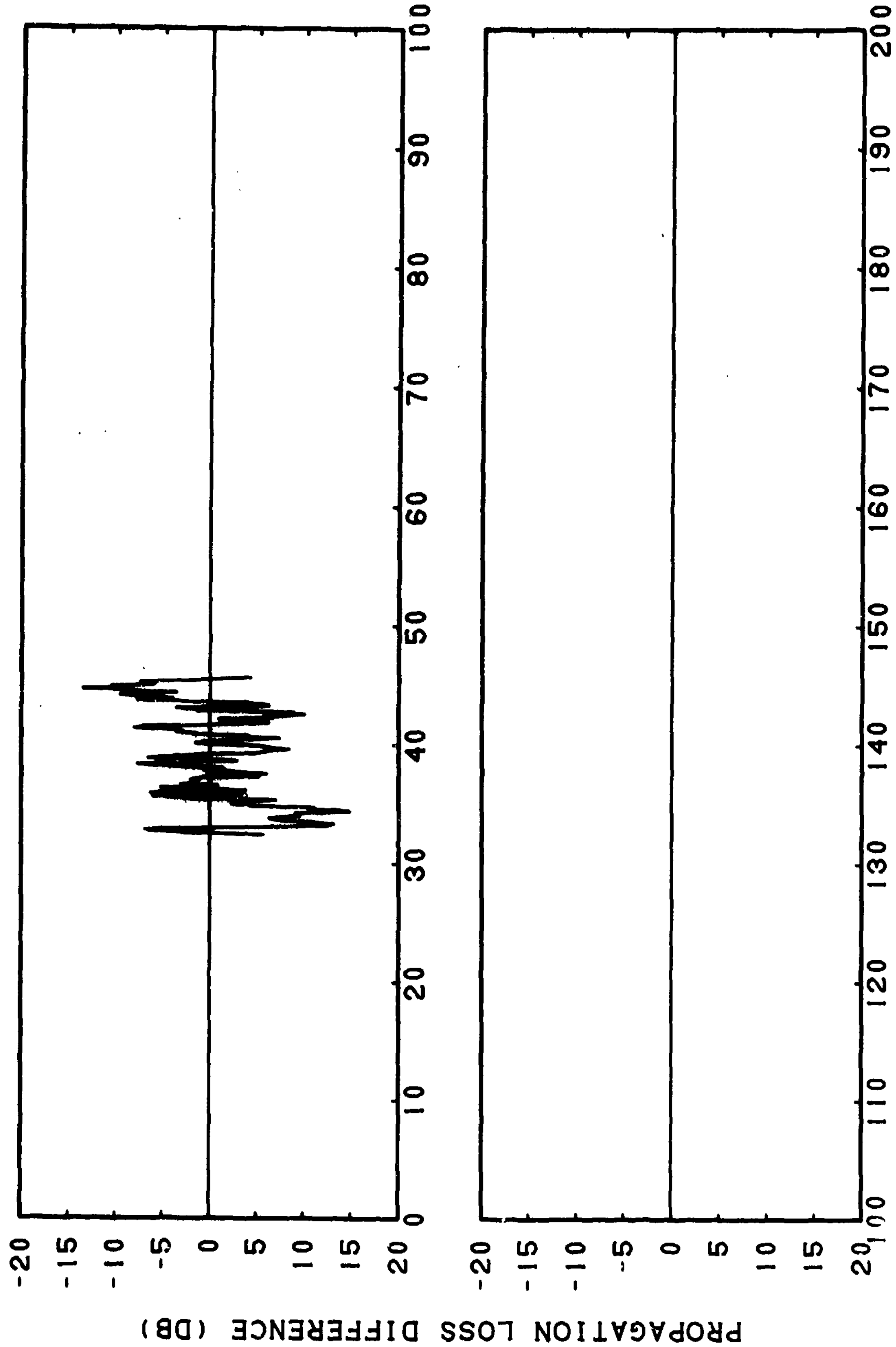
CONFIDENTIAL

(C) Figure IIF-11b. RAYMODE Coherent Station 2 Run 63, Source Depth = 20 Feet, Receiver Depth = 60 Feet



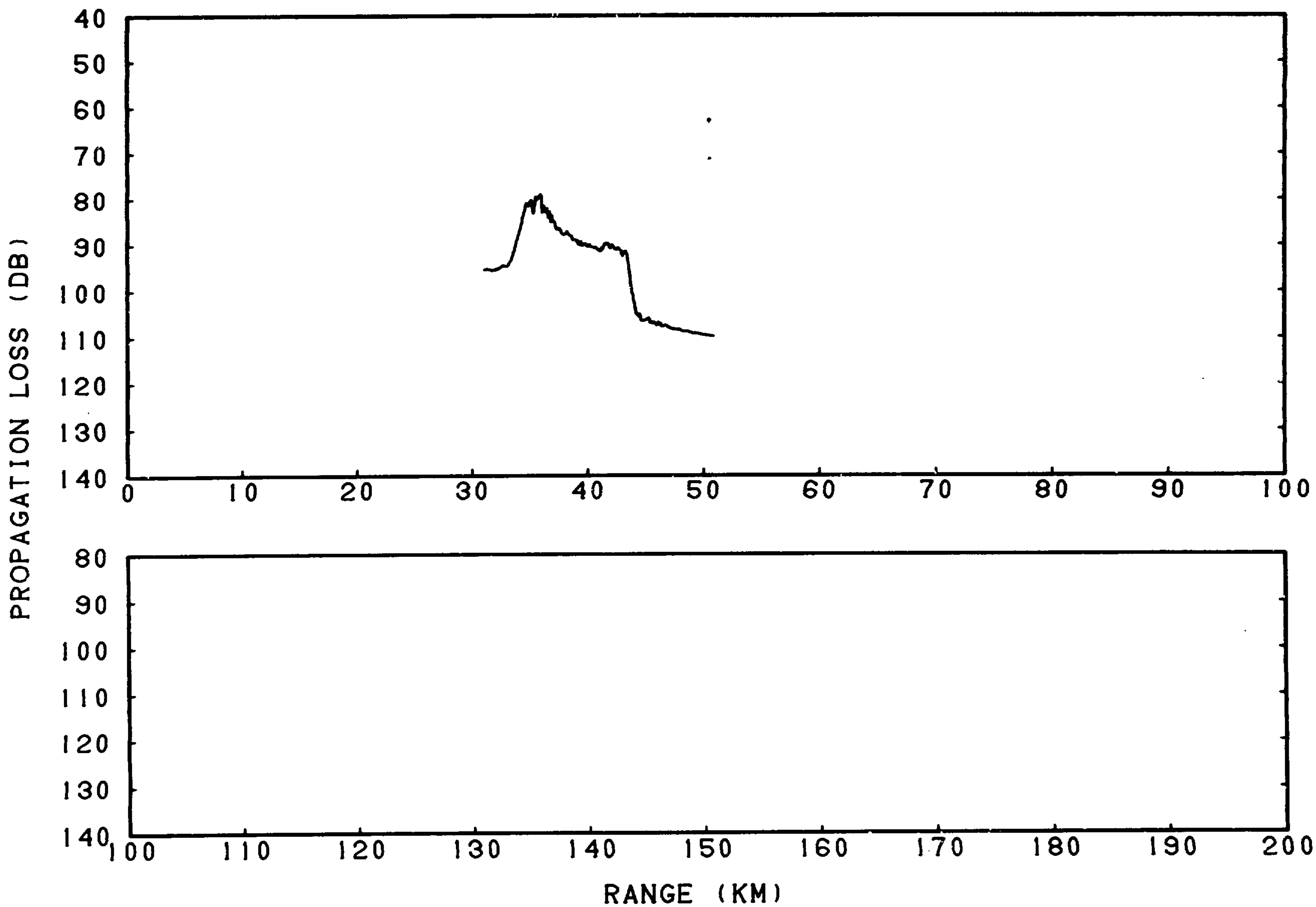
CONFIDENTIAL

(C) Figure IIIF-11c. RAYMODE Coherent Station 2 Run 63, Source Depth = 20 Feet, Receiver Depth = 60 Feet, Sliding Averages of 5 Points (0.39 Kilometer)



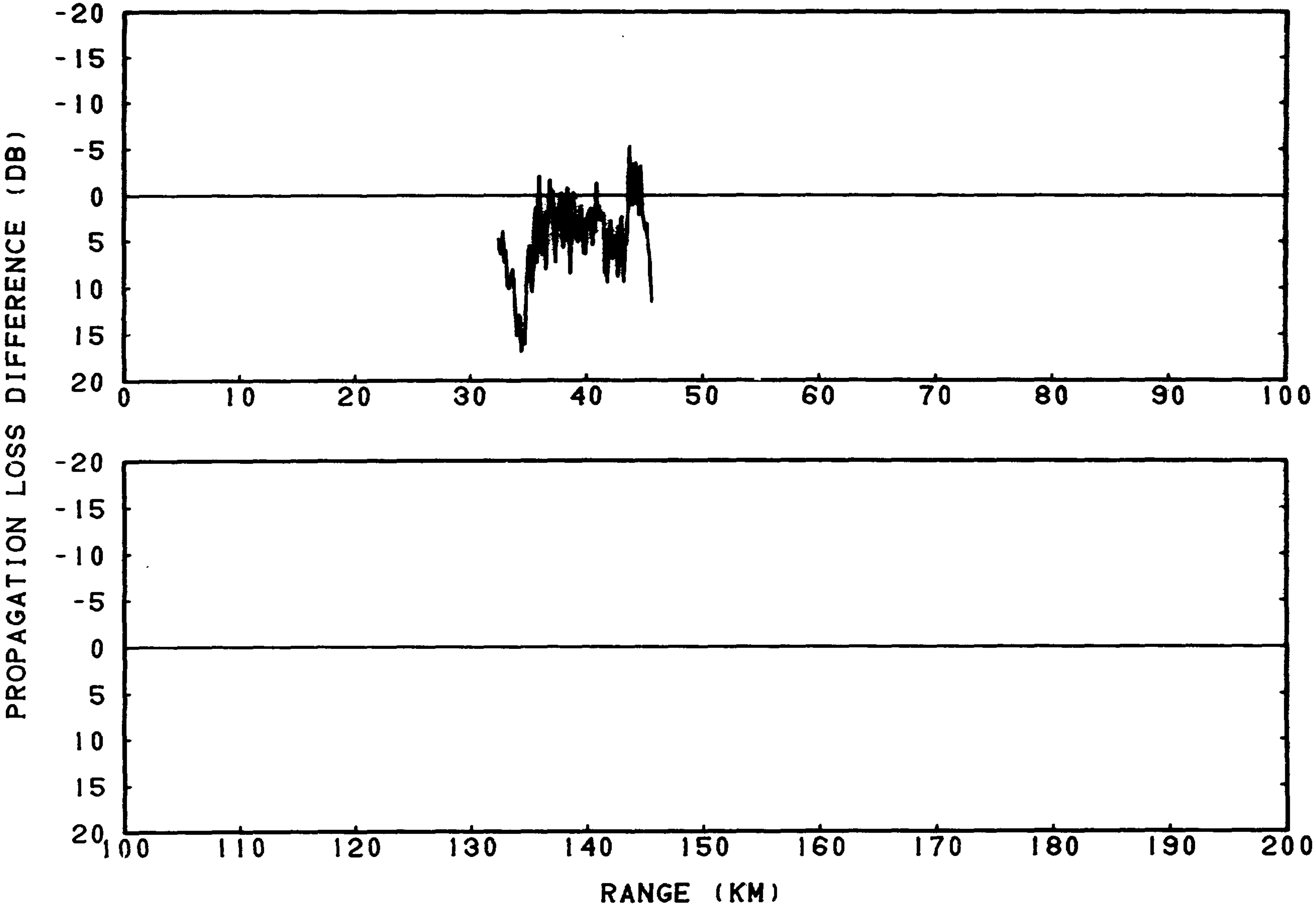
CONFIDENTIAL

(C) Figure IIIF-11d. Smoothed RAYMODE Coherent Station 2 Run 63, Source Depth = 20 Feet, Receiver Depth = 60 Feet, Subtracted from Station 2 Run 63, Source Depth = 20 Feet, Receiver Depth = 60 Feet



CONFIDENTIAL

(C) Figure IIIF-11e. RAYMODE Incoherent Station 2 Run 63, Source Depth = 20 Feet, Receiver Depth = 60 Feet



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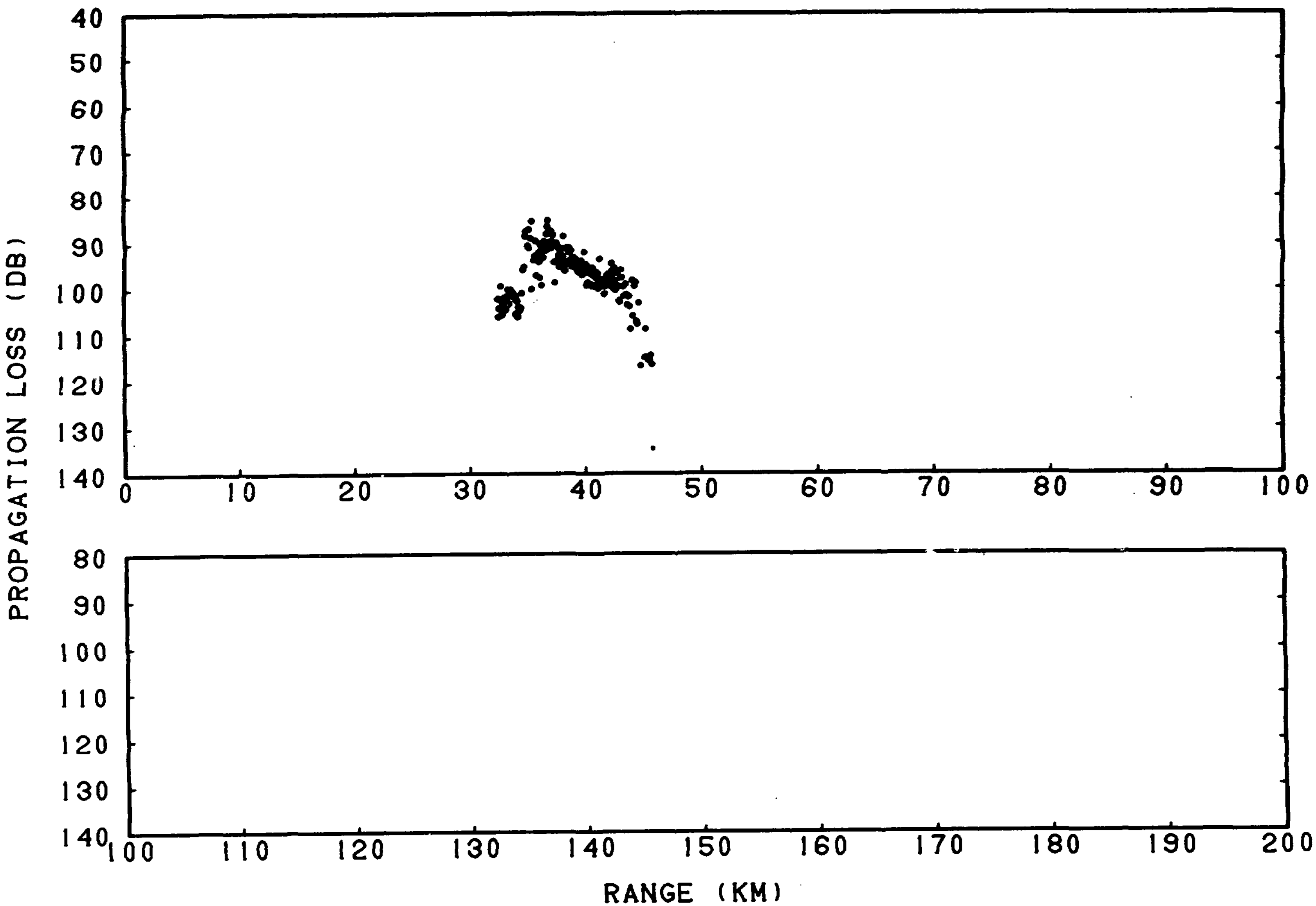
(C) Figure IIIF-11f. RAYMODE Incoherent Station 2 Run 63, Source Depth = 20 Feet, Receiver Depth = 60 Feet, Subtracted from Station 2 Run 63, Source Depth = 20 Feet, Receiver Depth = 60 Feet



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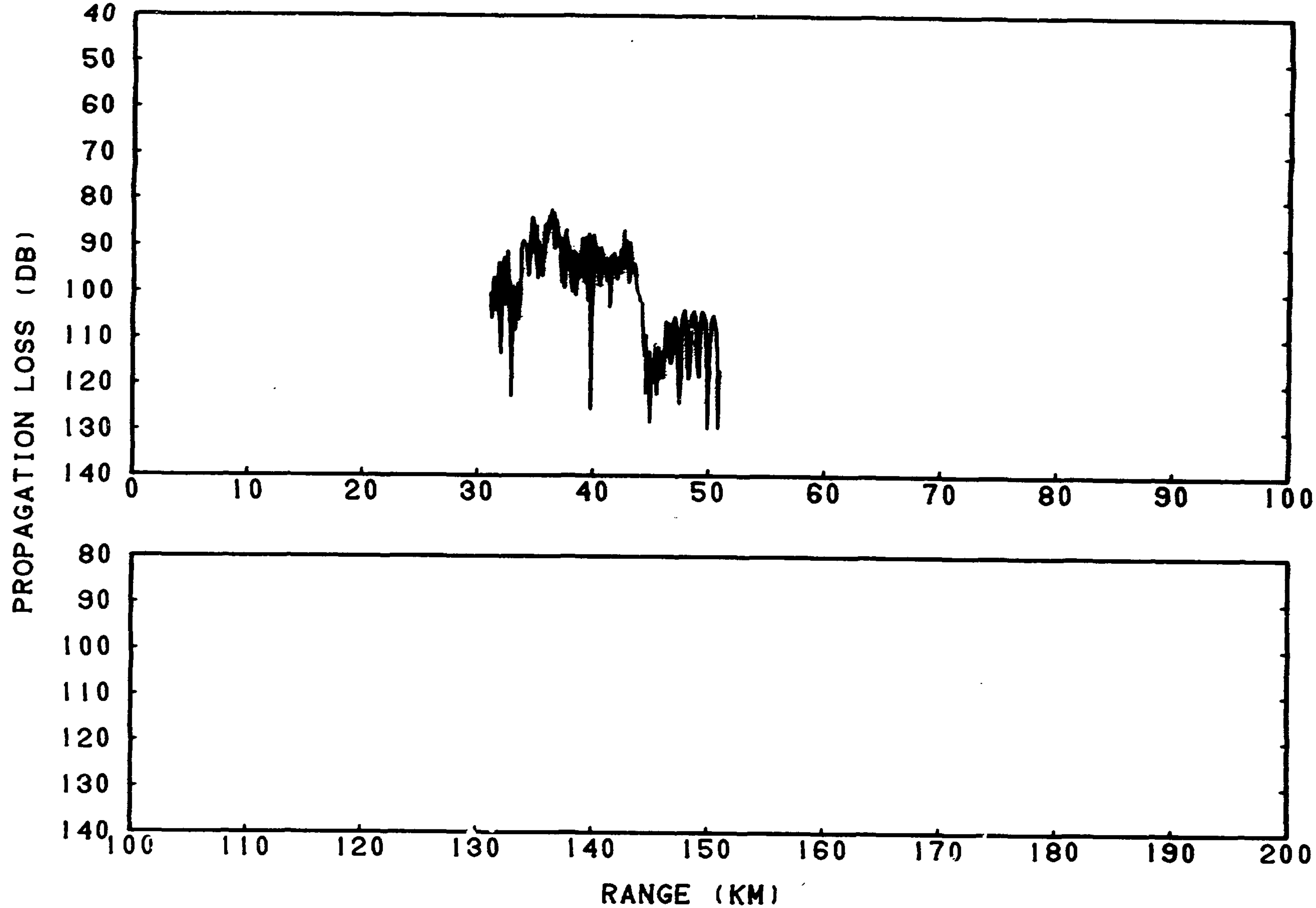
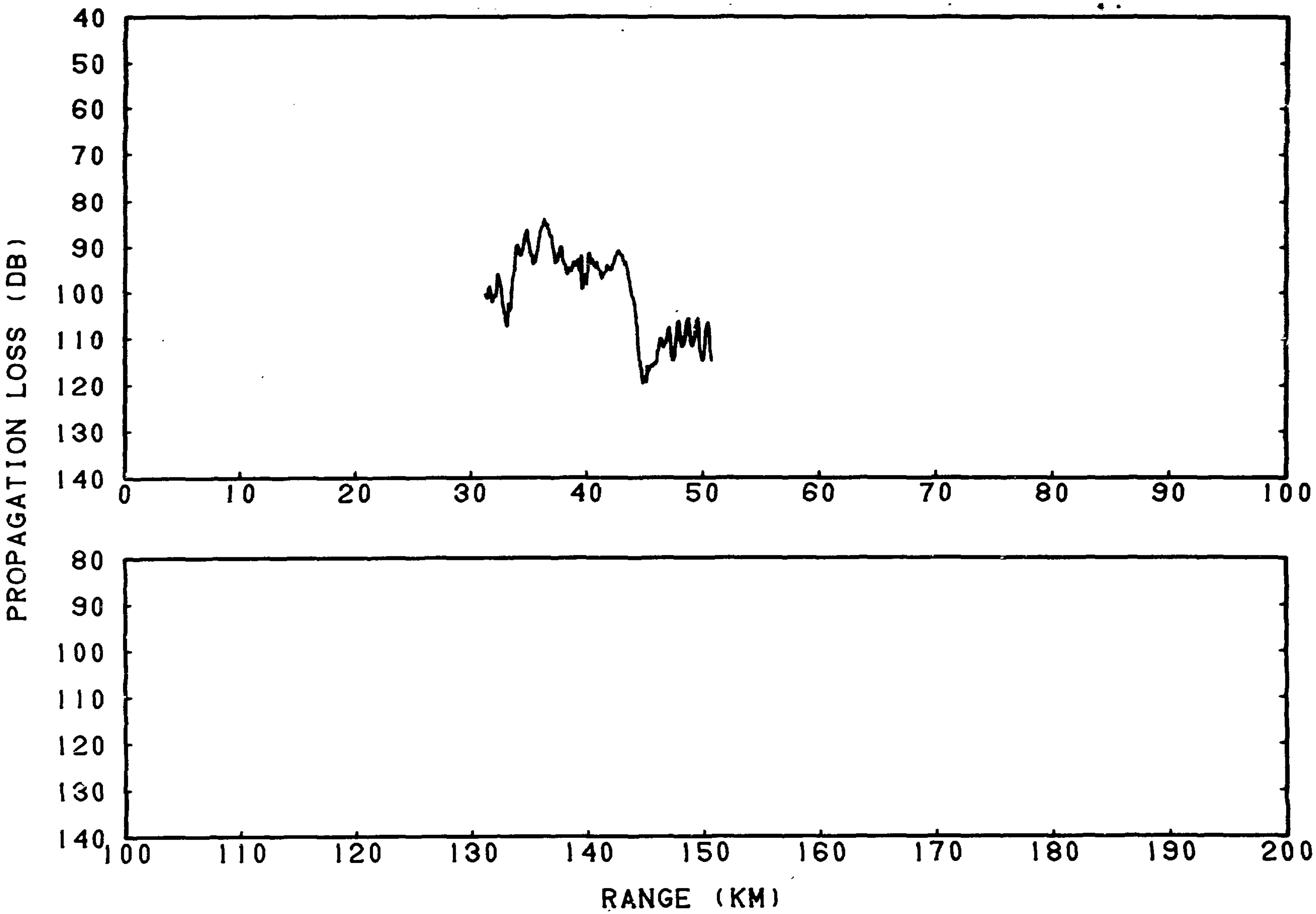
(C) Figure IIIF-12a. Station 2 Run 63, Source Depth = 20 Feet, Receiver Depth = 260 Feet



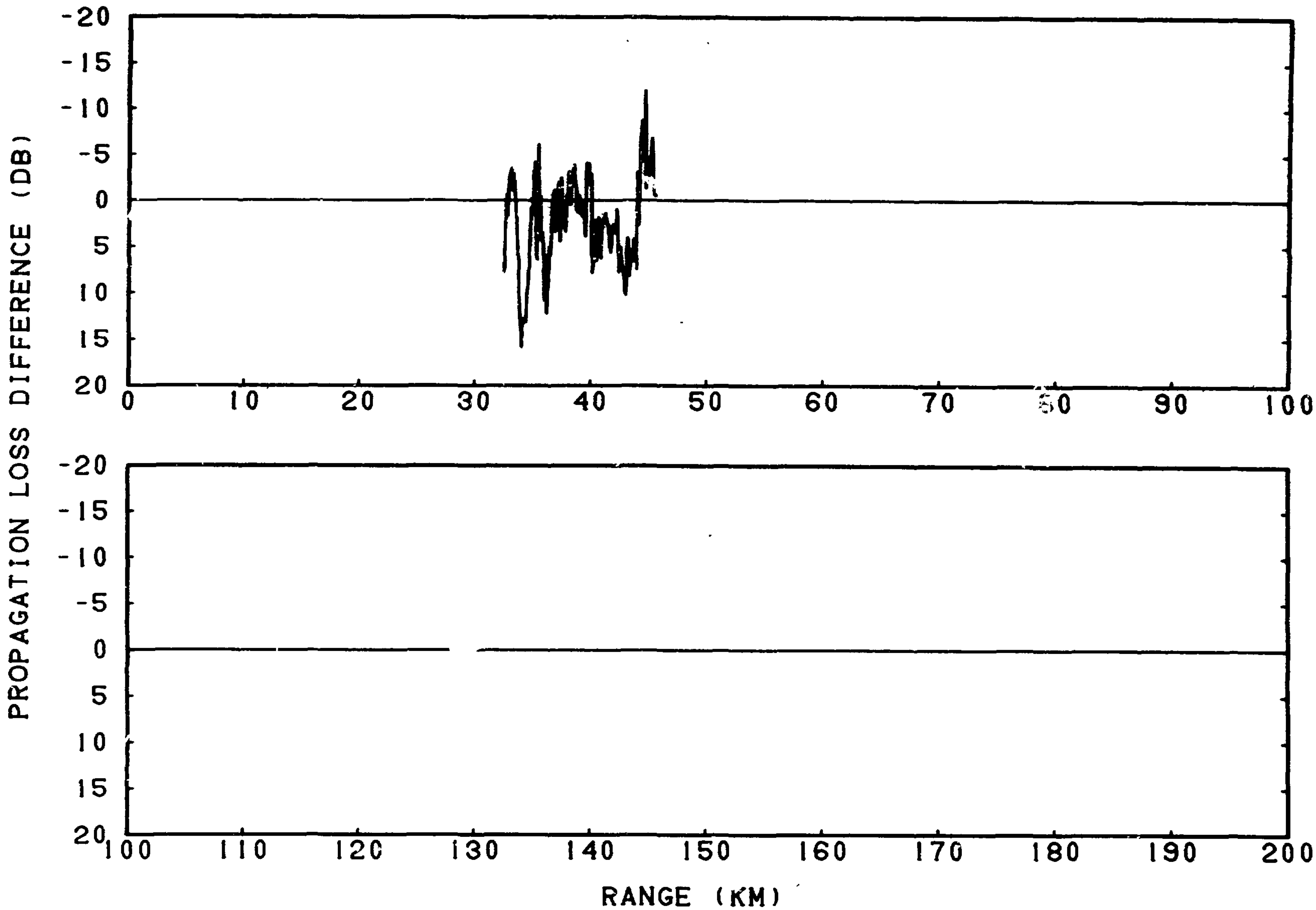
CONFIDENTIAL

(C) Figure IIIF-12b. RAYMODE Coherent Station 2 Run 63, Source Depth = 20 Feet, Receiver Depth = 260 Feet



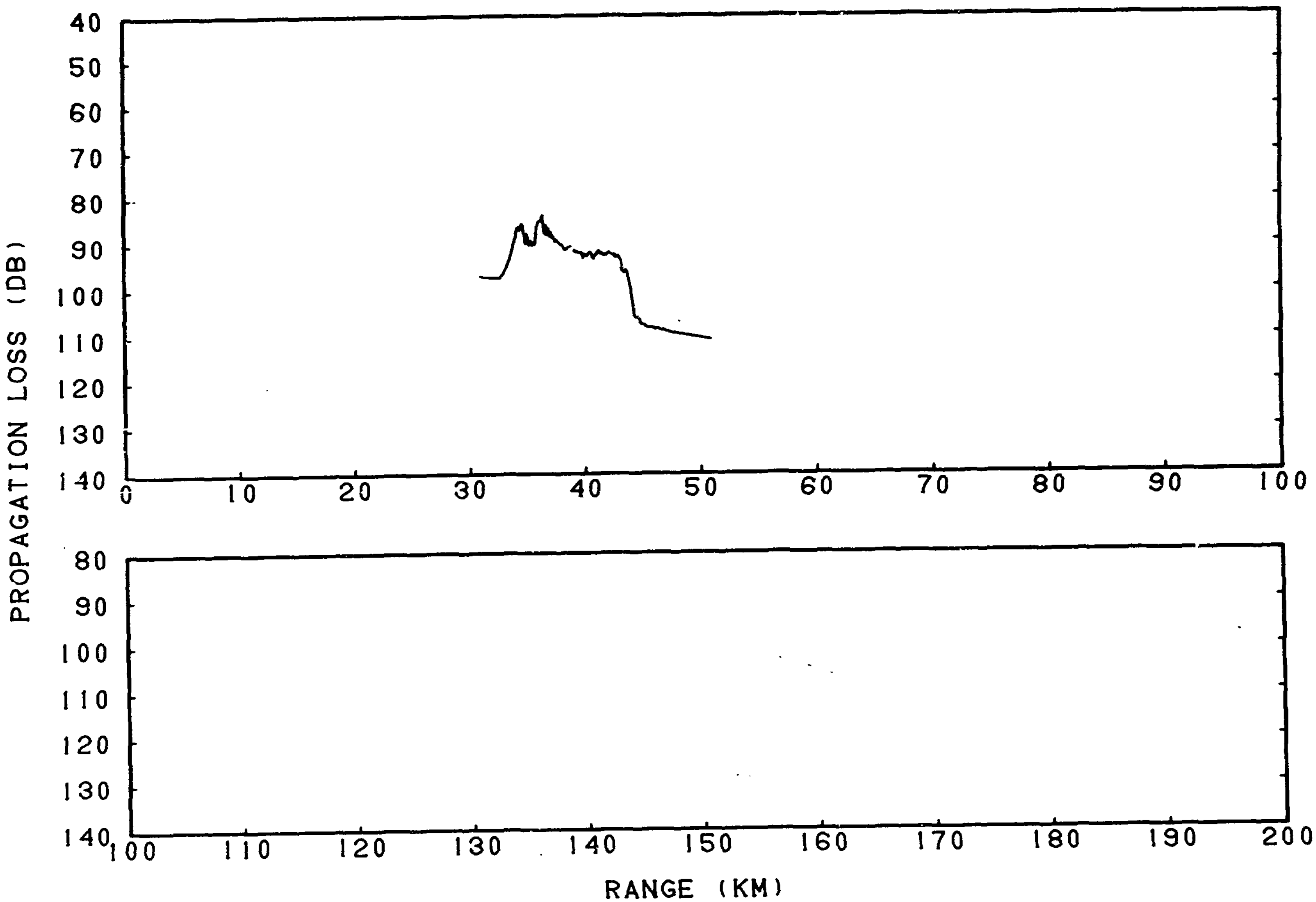
CONFIDENTIAL

(C) Figure IIIF-12c. RAYMODE Coherent Station 2 Run 63, Source Depth = 20 Feet, Receiver Depth = 260 Feet, Sliding Averages of 5 Points (0.39 Kilometer)



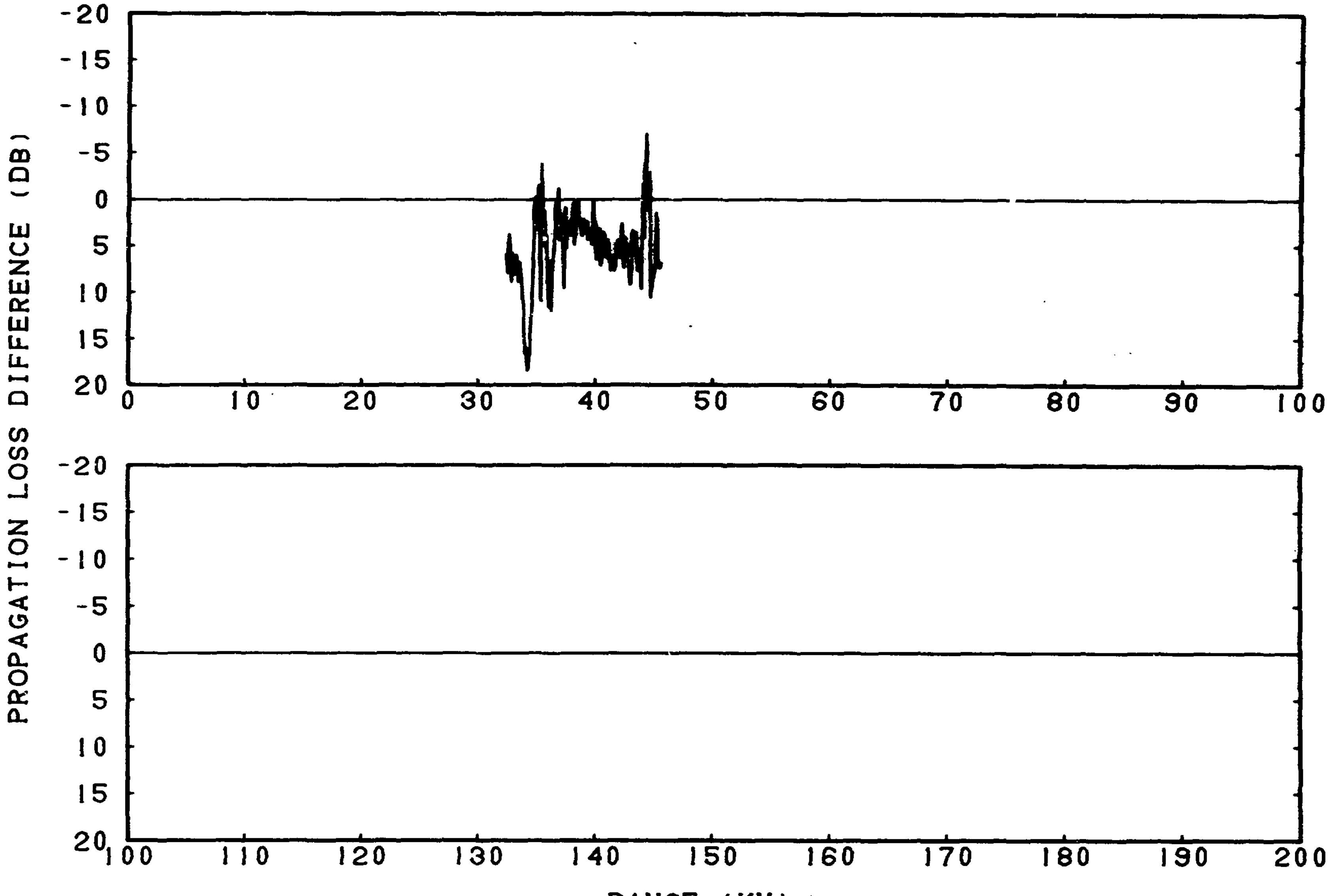
CONFIDENTIAL

(C) Figure IIIF-12d. Smoothed RAYMODE Coherent Station 2 Run 63, Source Depth = 20 Feet, Receiver Depth = 260 Feet, Subtracted from Station 2 Run 63, Source Depth = 20 Feet, Receiver Depth = 260 Feet



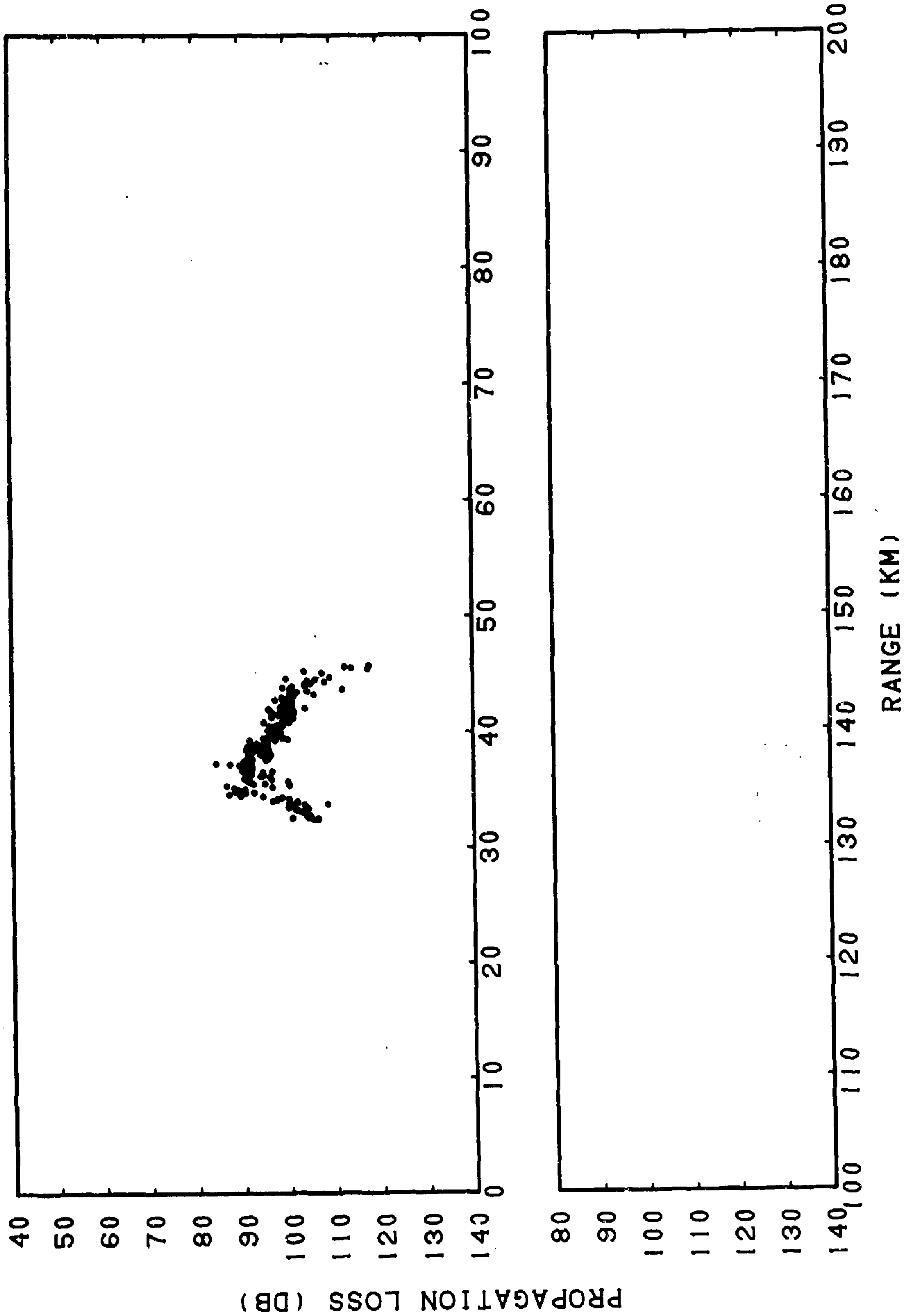
CONFIDENTIAL

(C) Figure IIIF-12e. RAYMODE Incoherent Station 2 Run 63, Source Depth = 20 Feet, Receiver Depth = 260 Feet



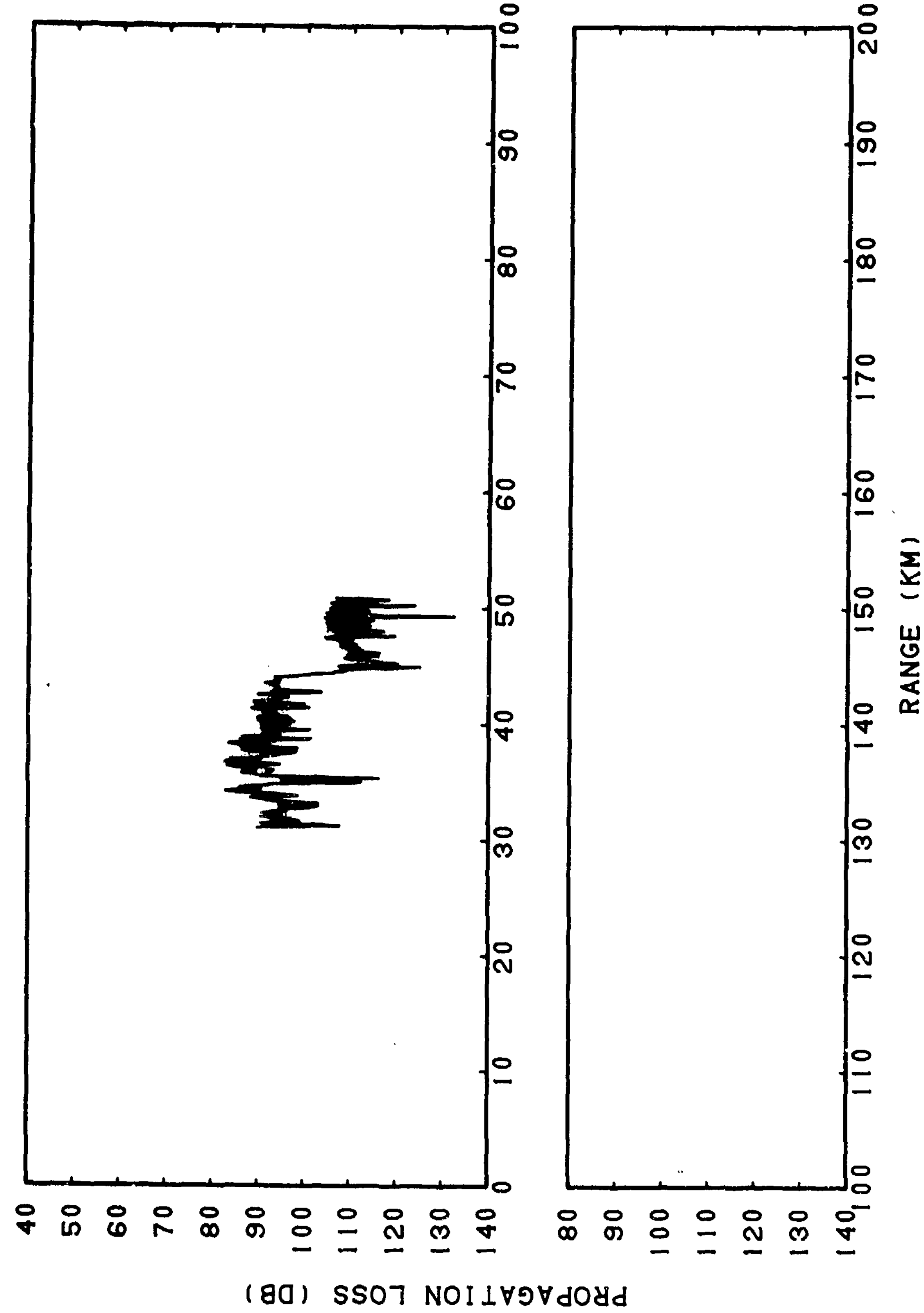
CONFIDENTIAL

(C) Figure IIIF-12f. RAYMODE Incoherent Station 2 Run 63, Source Depth = 20 Feet, Receiver Depth = 260 Feet, Subtracted from Station 2 Run 63, Source Depth = 20 Feet, Receiver Depth = 260 Feet



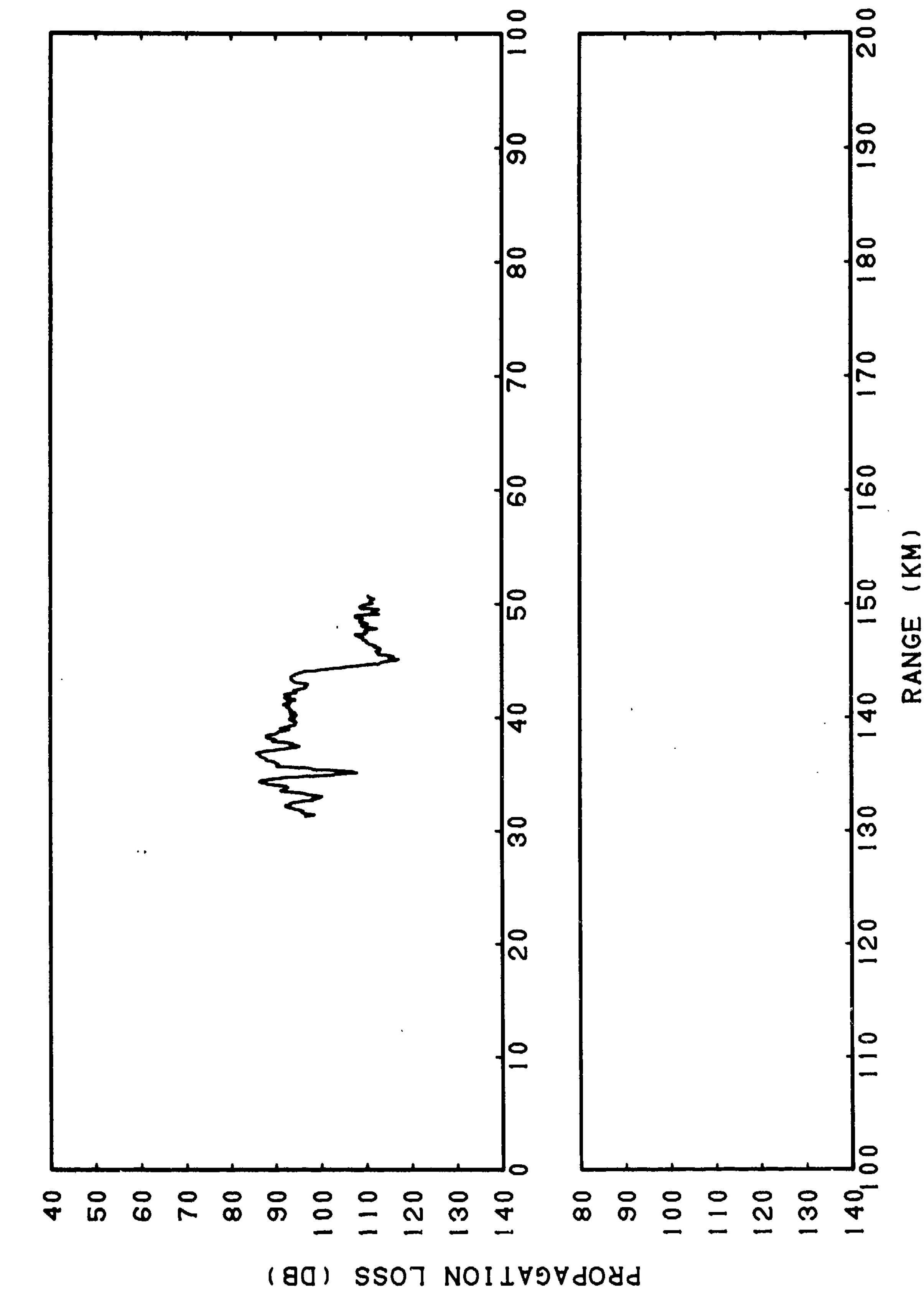
CONFIDENTIAL

(C) Figure IIIF-13a. Station 2 Run 63, Source Depth = 20 Feet, Receiver Depth = 535 Feet



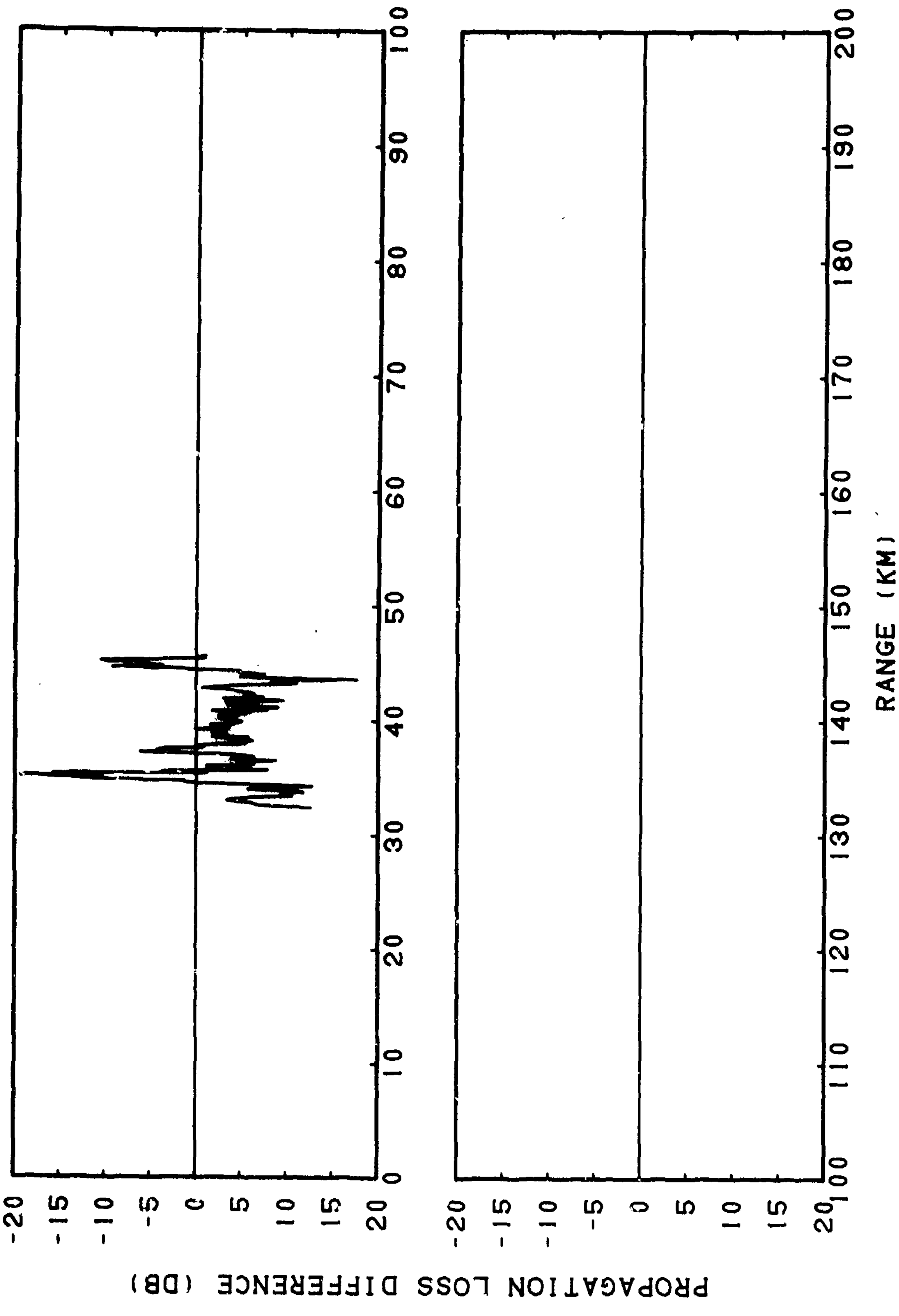
CONFIDENTIAL

(C) Figure IIIF-13b. RAYMODE Coherent Station 2 Run 63, Source Depth = 20 Feet, Receiver Depth = 535 Feet



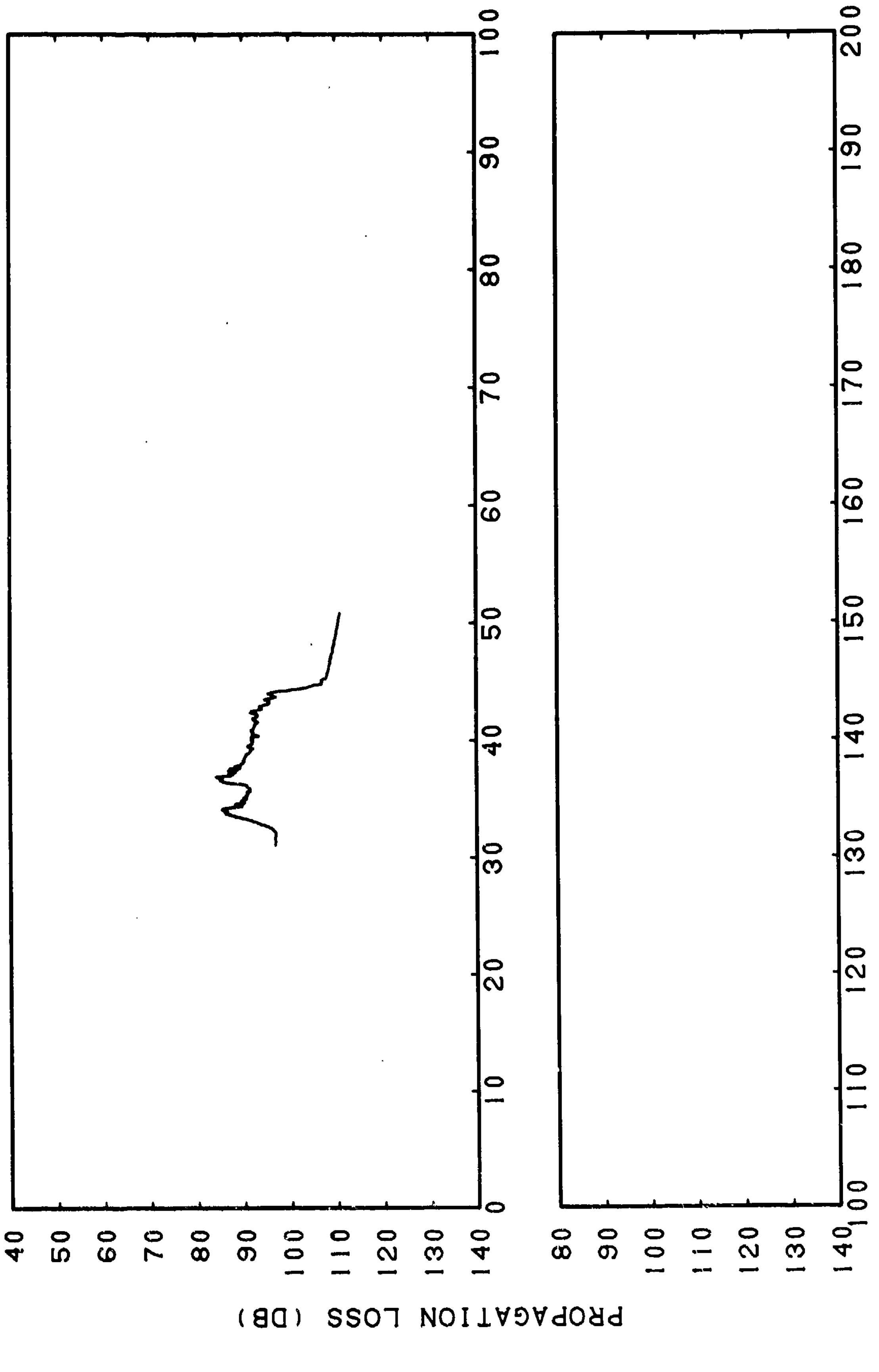
CONFIDENTIAL

(C) Figure IIIF-13c. RAYMODE Coherent Station 2 Run 63, Source Depth = 20 Feet, Receiver Depth = 535 Feet, Sliding Averages of 5 Points (0.39 Kilometer.)



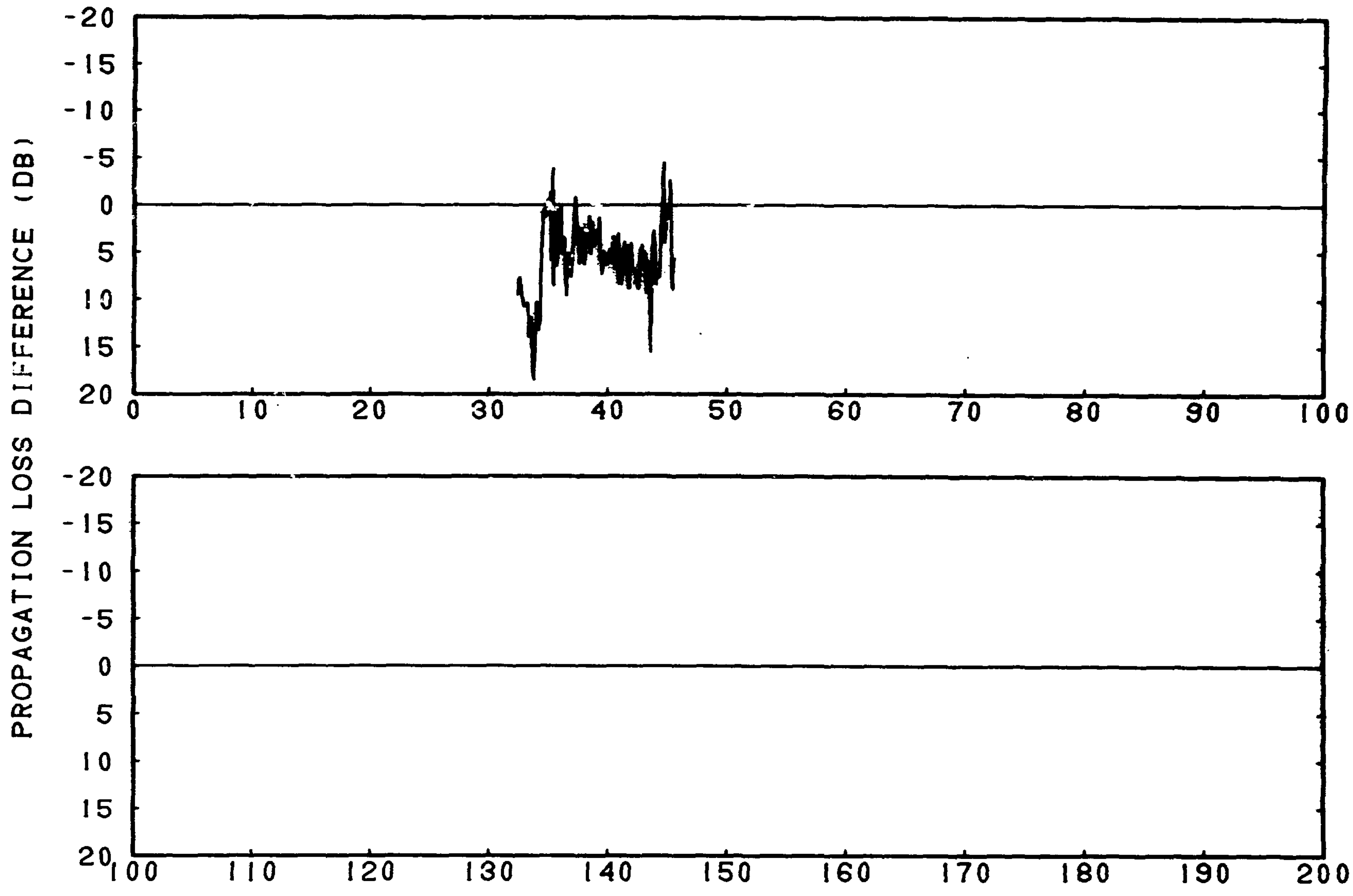
CONFIDENTIAL

(C) Figure IIIF-13d. Smoothed RAYMODE Coherent Station 2 Run 63, Source Depth = 20 Feet, Receiver Depth = 535 Feet, Subtracted from Station 2 Run 63, Source Depth = 20 Feet, Receiver Depth = 535 Feet



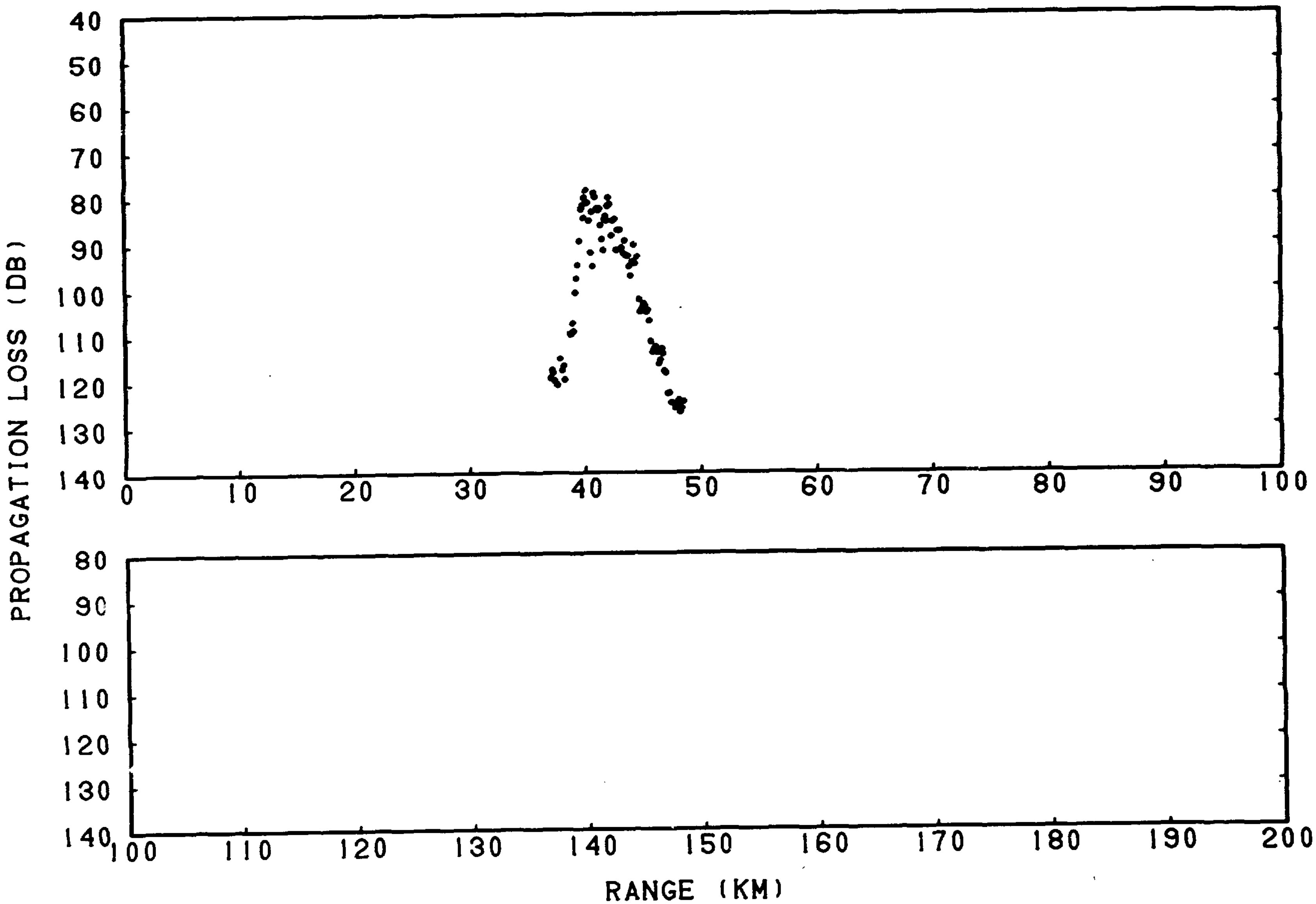
CONFIDENTIAL

(C) Figure IIIF-13e. RAYMODE Incoherent Station 2 Run 63, Source Depth = 20 Feet, Receiver Depth = 535 Feet



CONFIDENTIAL

(C) Figure IIIF-13f. RAYMODE Incoherent Station 2 Run 63, Source Depth = 20 Feet, Receiver Depth = 535 Feet, Subtracted from Station 2 Run 63, Source Depth = 20 Feet, Receiver Depth = 535 Feet



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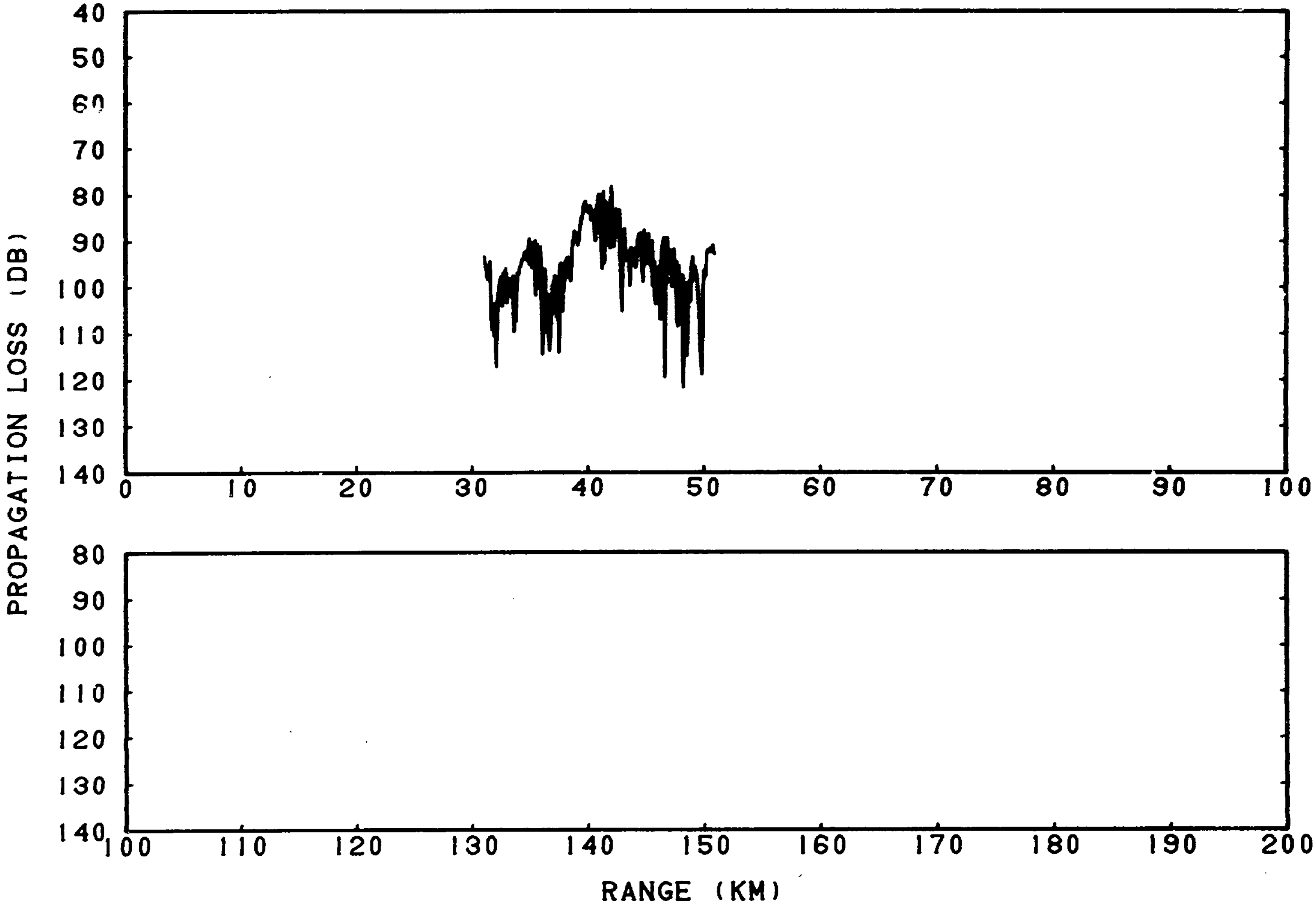
(C) Figure IIIF-14a. Station 3 Run 43, Source Depth = 20 Feet, Receiver Depth = 60 Feet



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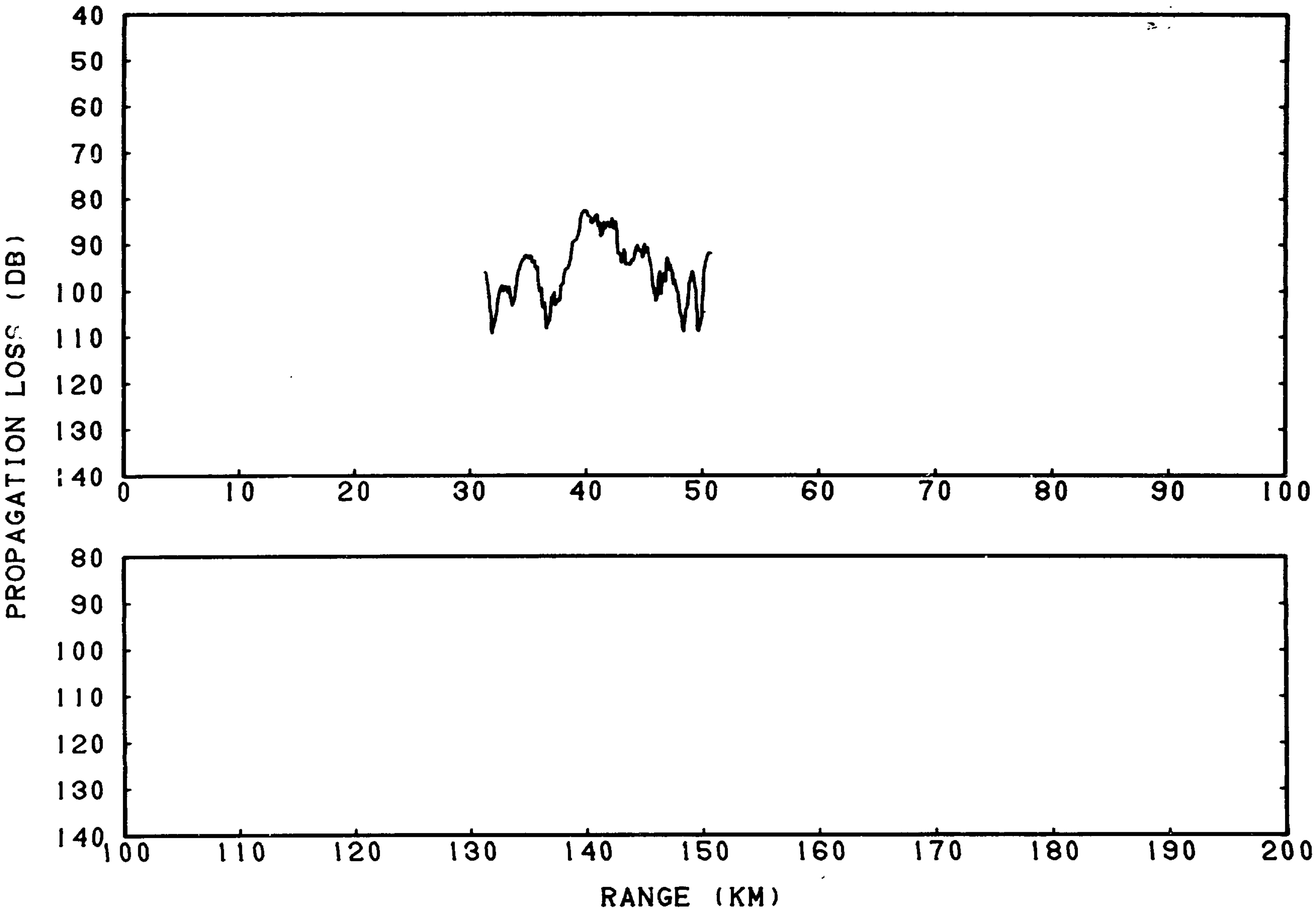
(C) Figure IIIF-14b. RAYMODE Coherent Station 3 Run 43, Source Depth = 20 Feet, Receiver Depth = 60 Feet



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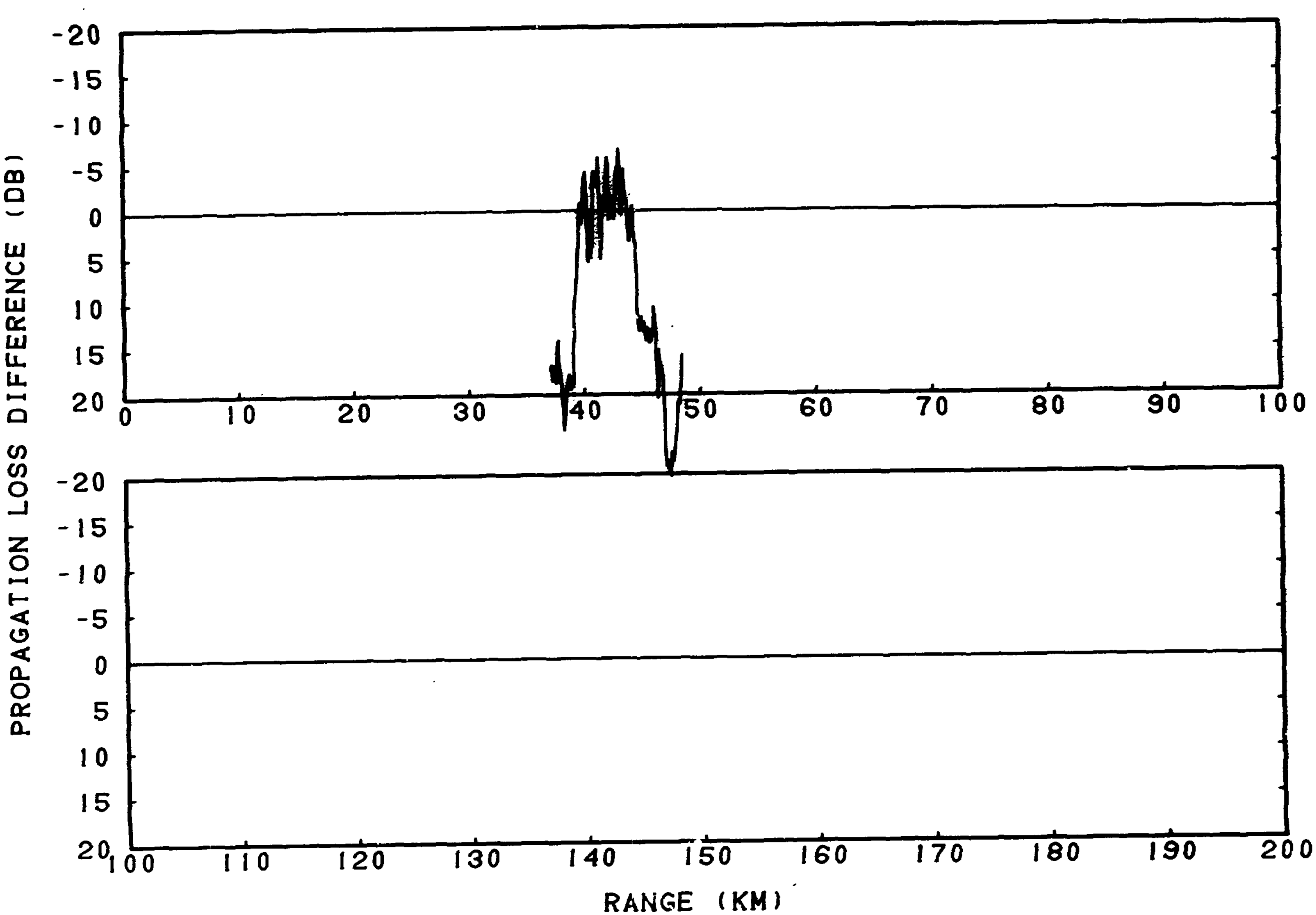
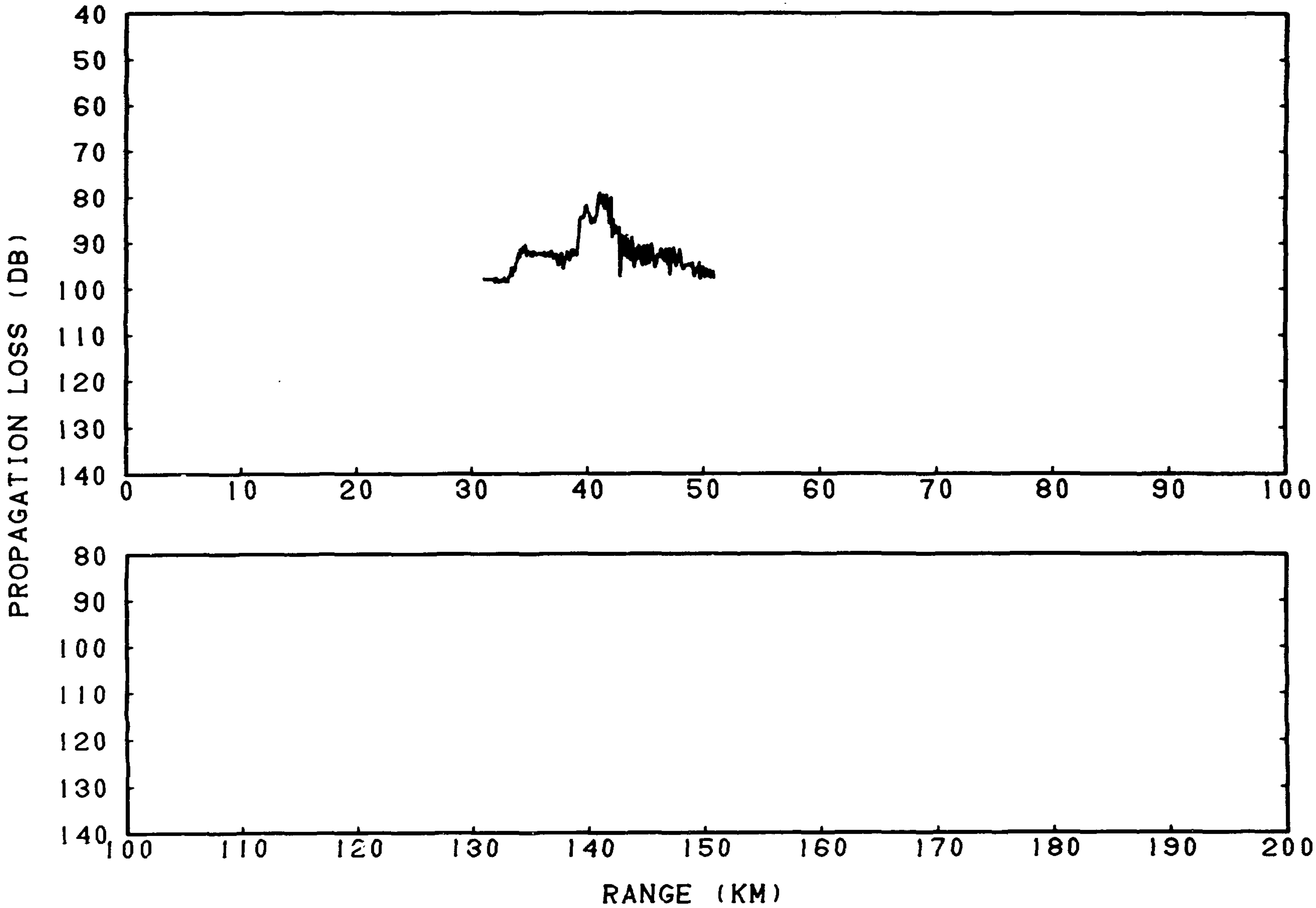
(C) Figure IIIF-14c. RAYMODE Coherent Station 3 Run 43, Source Depth = 20 Feet, Receiver Depth = 60 Feet, Sliding Averages of 5 Points (0.39 Kilometer)



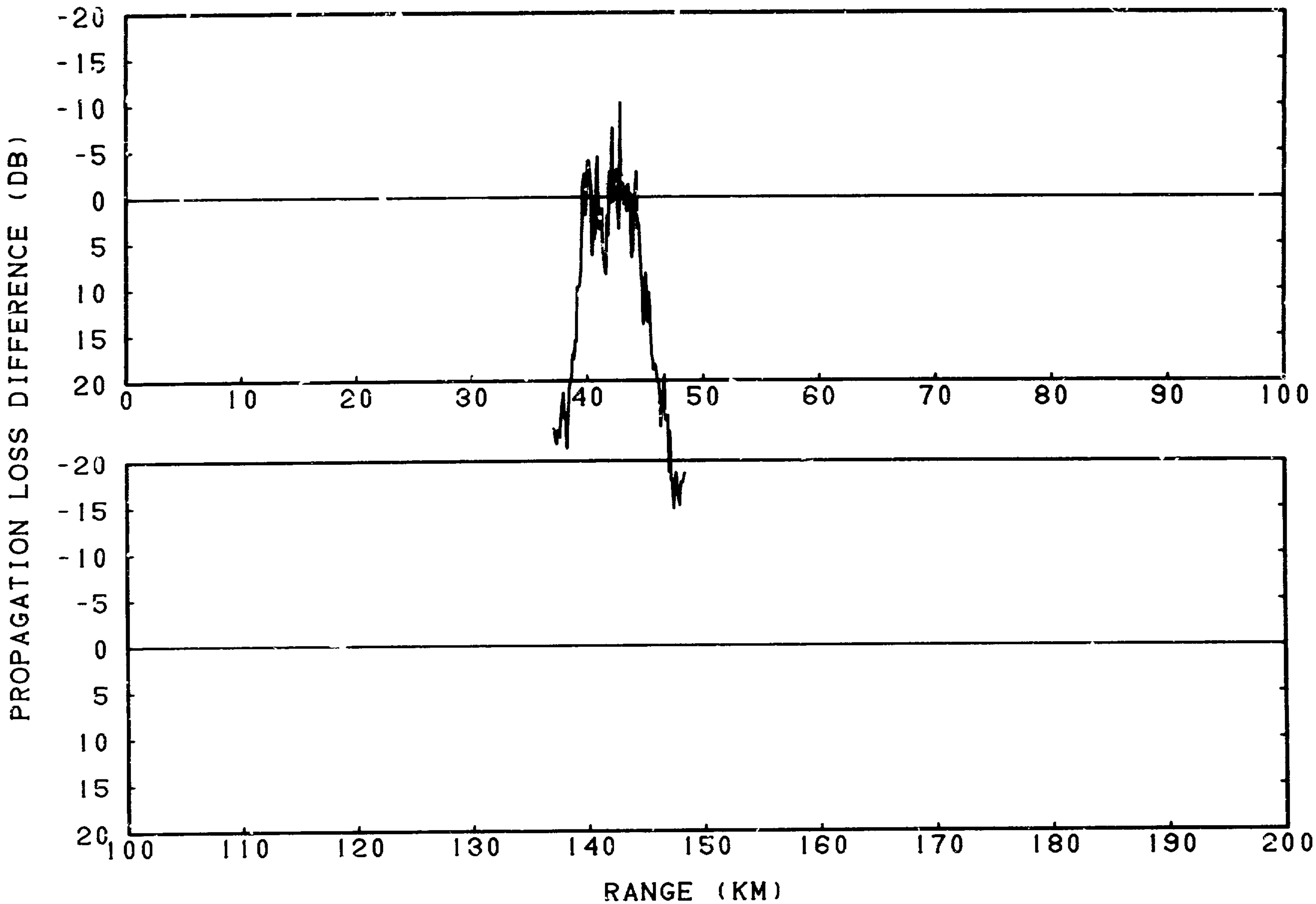
CONFIDENTIAL

(C) Figure IIIF-14d. Smoothed RAYMODE Coherent Station 3 Run 43, Source Depth = 20 Feet, Receiver Depth = 60 Feet, Subtracted from Station 3 Run 43, Source Depth = 20 Feet, Receiver Depth = 60 Feet



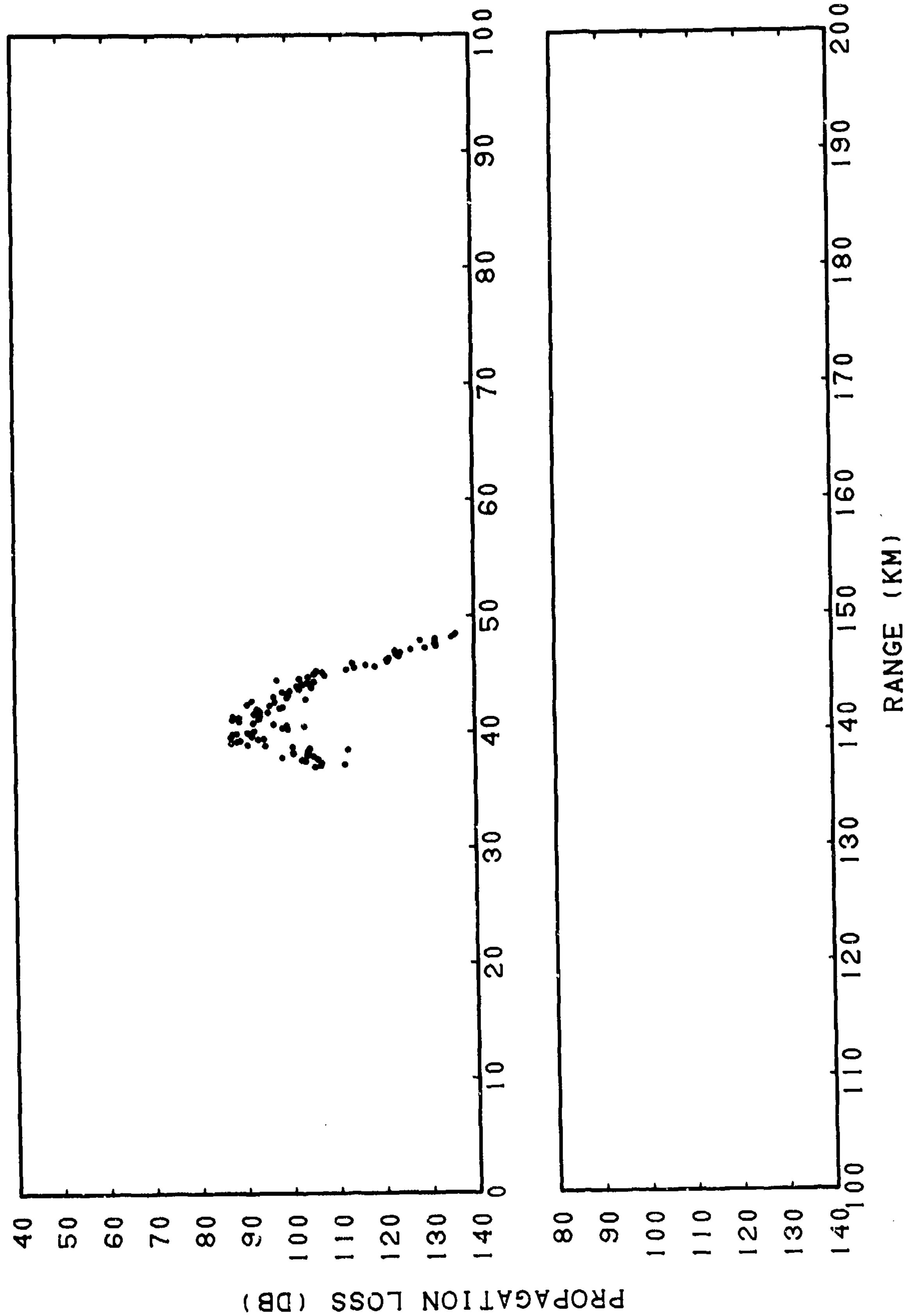
CONFIDENTIAL

(C) Figure IIIF-14e. RAYMODE Incoherent Station 3 Run 43, Source Depth = 20 Feet, Receiver Depth = 60 Feet



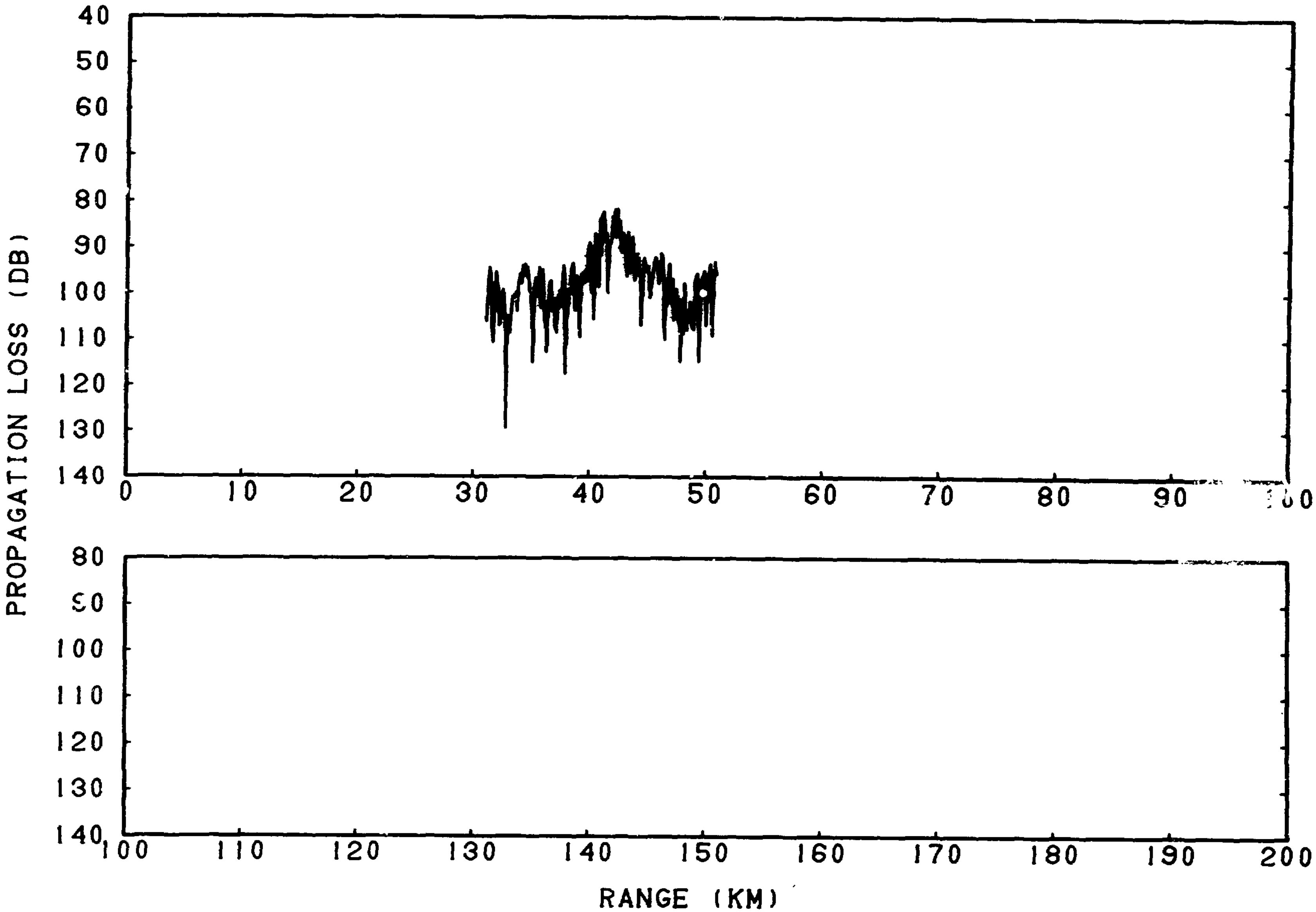
CONFIDENTIAL

(C) Figure IIIF-14f. RAYMODE Incoherent Station 3 Run 43, Source Depth = 20 Feet, Receiver Depth = 60 Feet, Subtracted from Station 3 Run 43, Source Depth = 20 Feet, Receiver Depth = 60 Feet



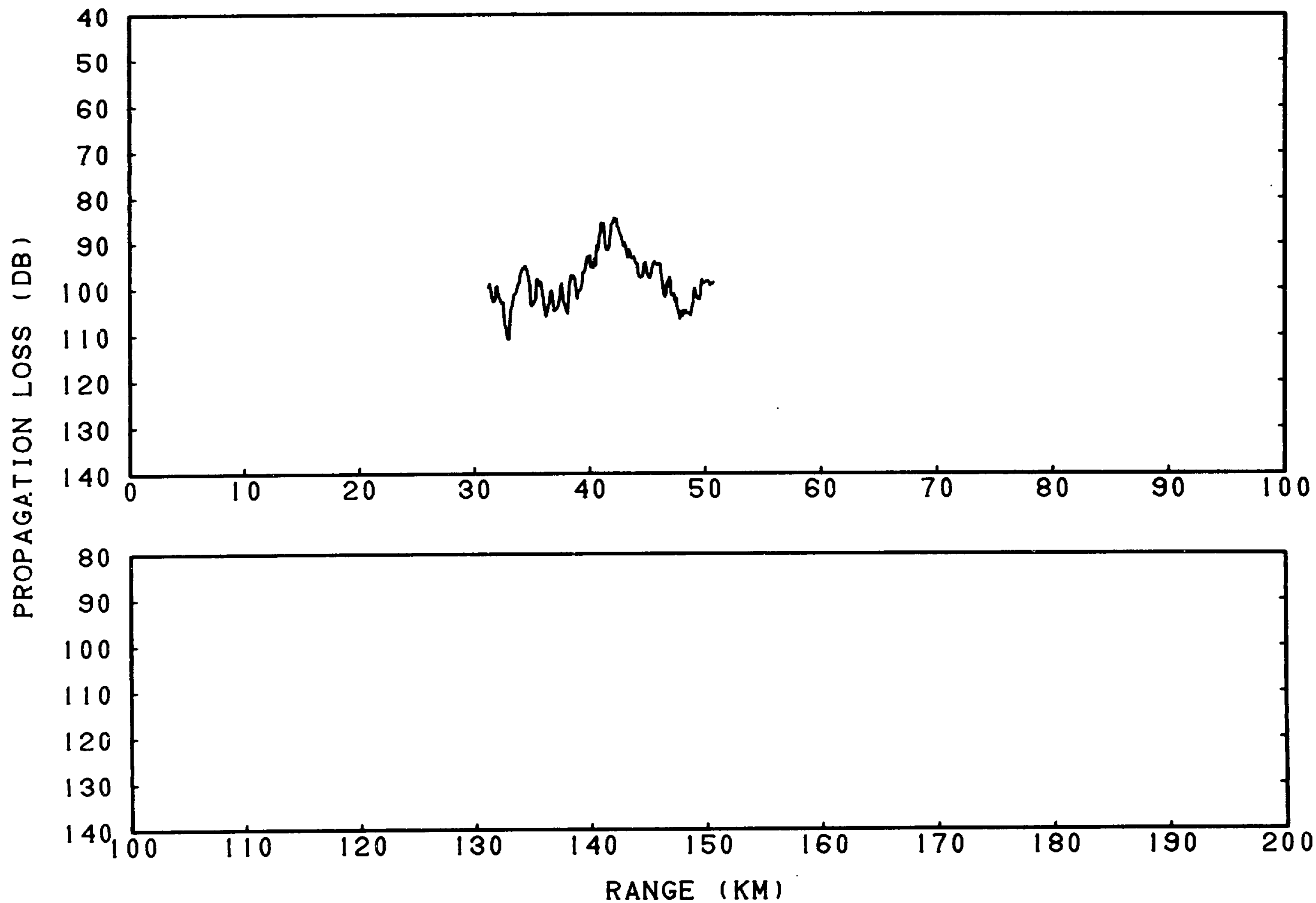
CONFIDENTIAL

(C) Figure IIF-15a. Station 3 Run 43, Source Depth = 20 Feet, Receiver Depth = 260 Feet



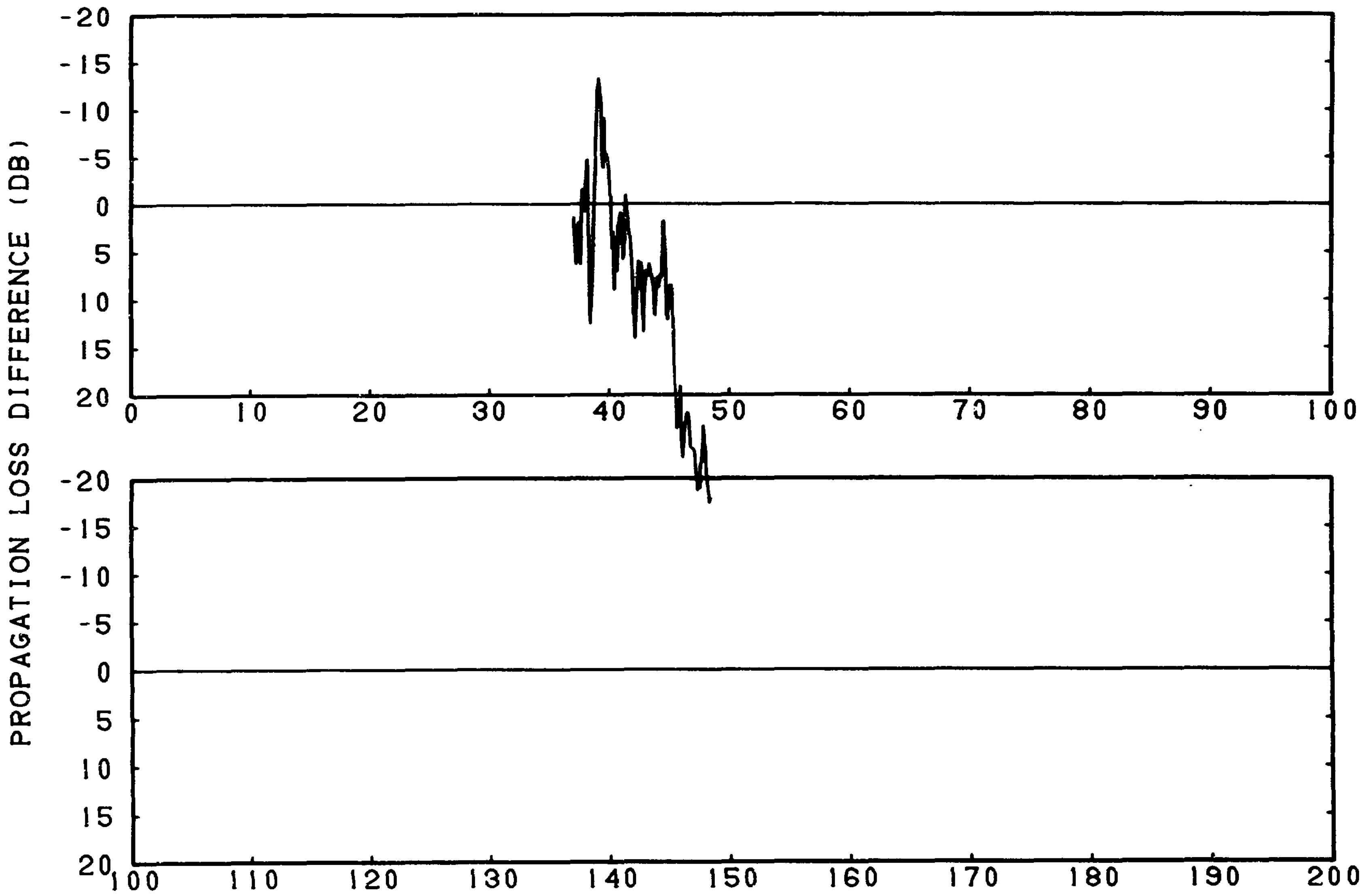
CONFIDENTIAL

(C) Figure IIIF-15b. RAYMODE Coherent Station 3 Run 43, Source Depth = 20 Feet, Receiver Depth = 260 Feet



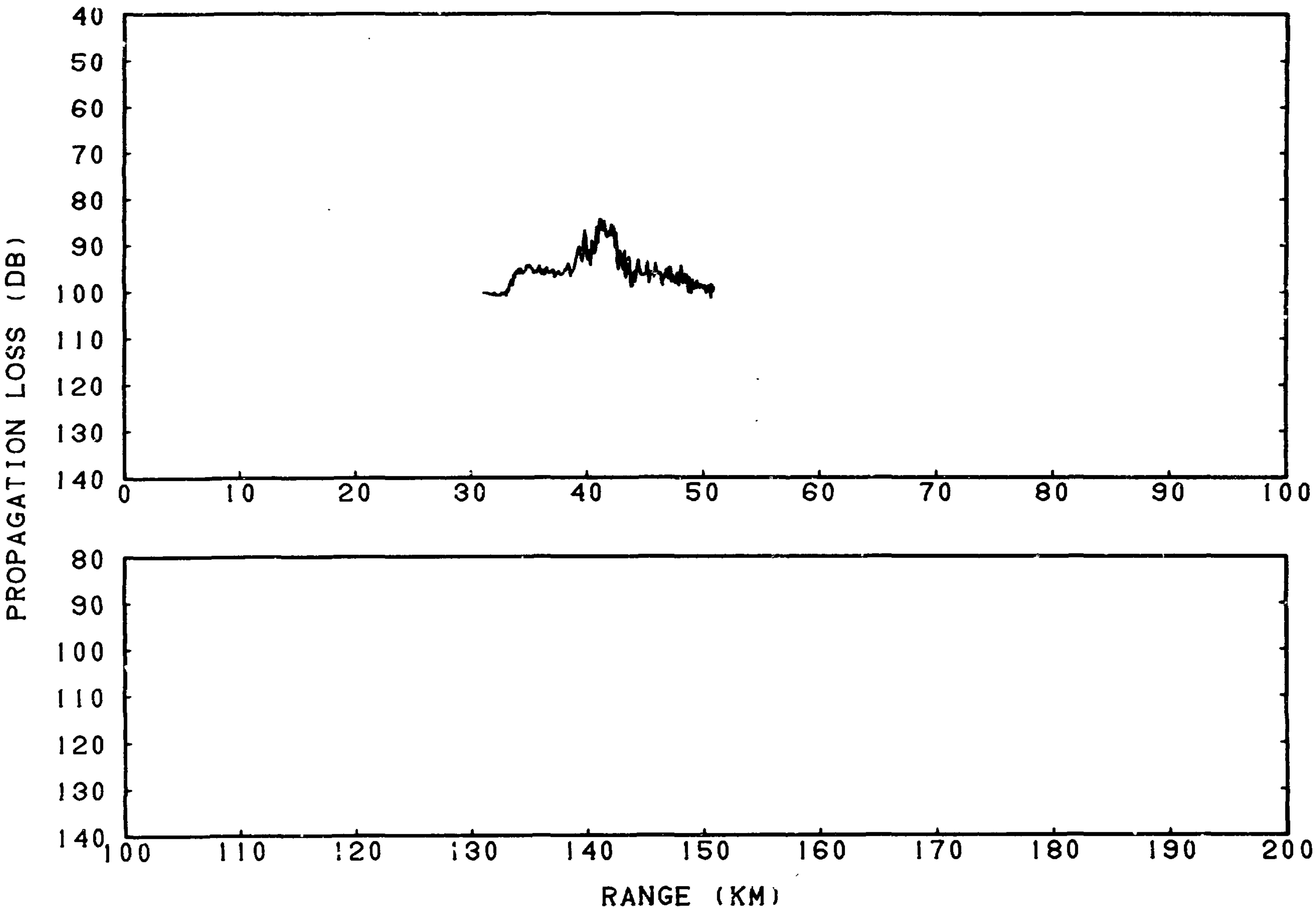
CONFIDENTIAL

(C) Figure IIIF-15c. RAYMODE Coherent Station 3 Run 43, Source Depth = 20 Feet, Receiver Depth = 260 Feet, Sliding Averages of 5 Points (0.39 Kilometer)



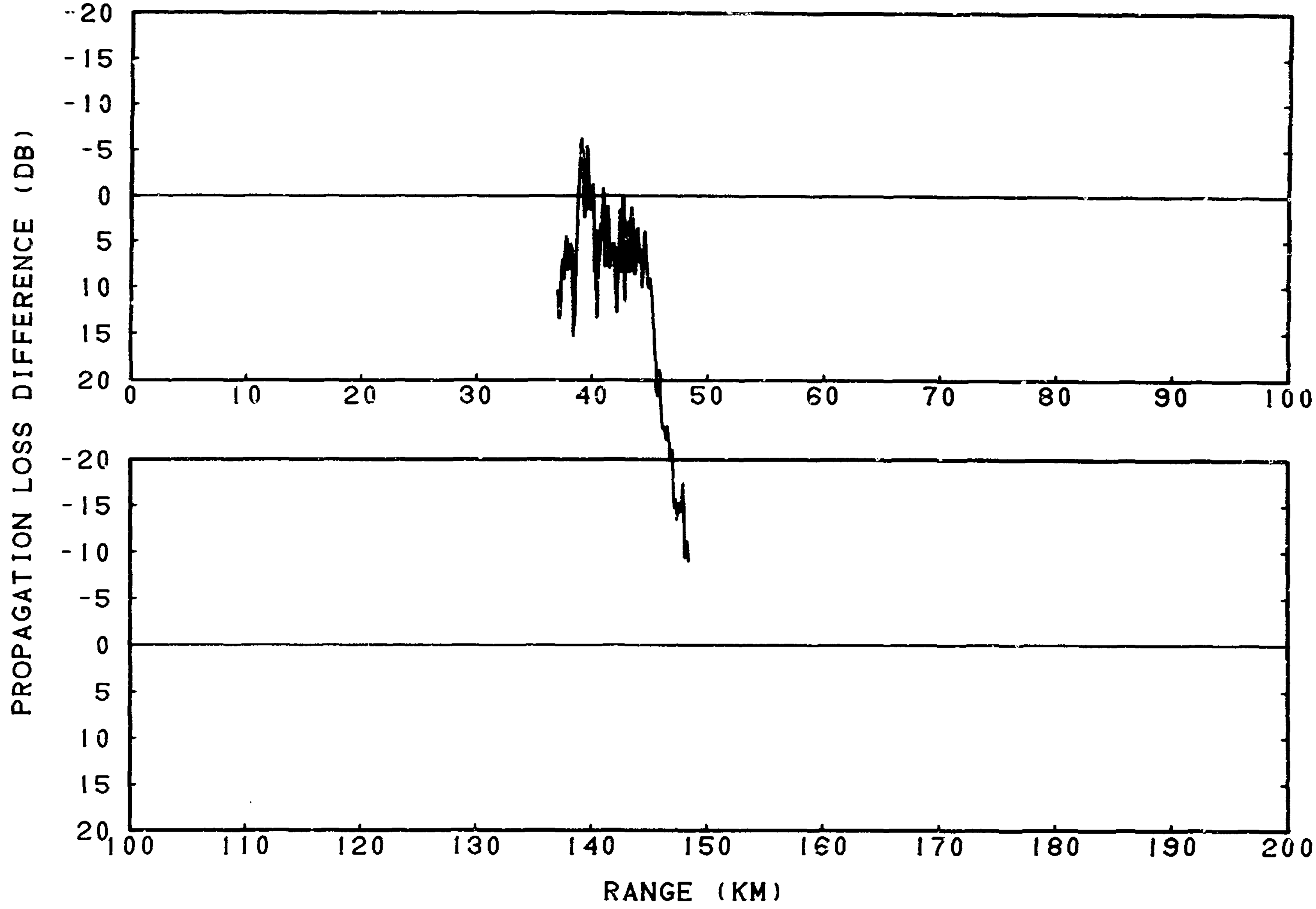
CONFIDENTIAL

(C) Figure IIIF-15d. Smoothed RAYMODE Coherent Station 3 Run 43, Source Depth = 20 Feet, Receiver Depth = 260 Feet, Subtracted from Station 3 Run 43, Source Depth = 20 Feet, Receiver Depth = 260 Feet



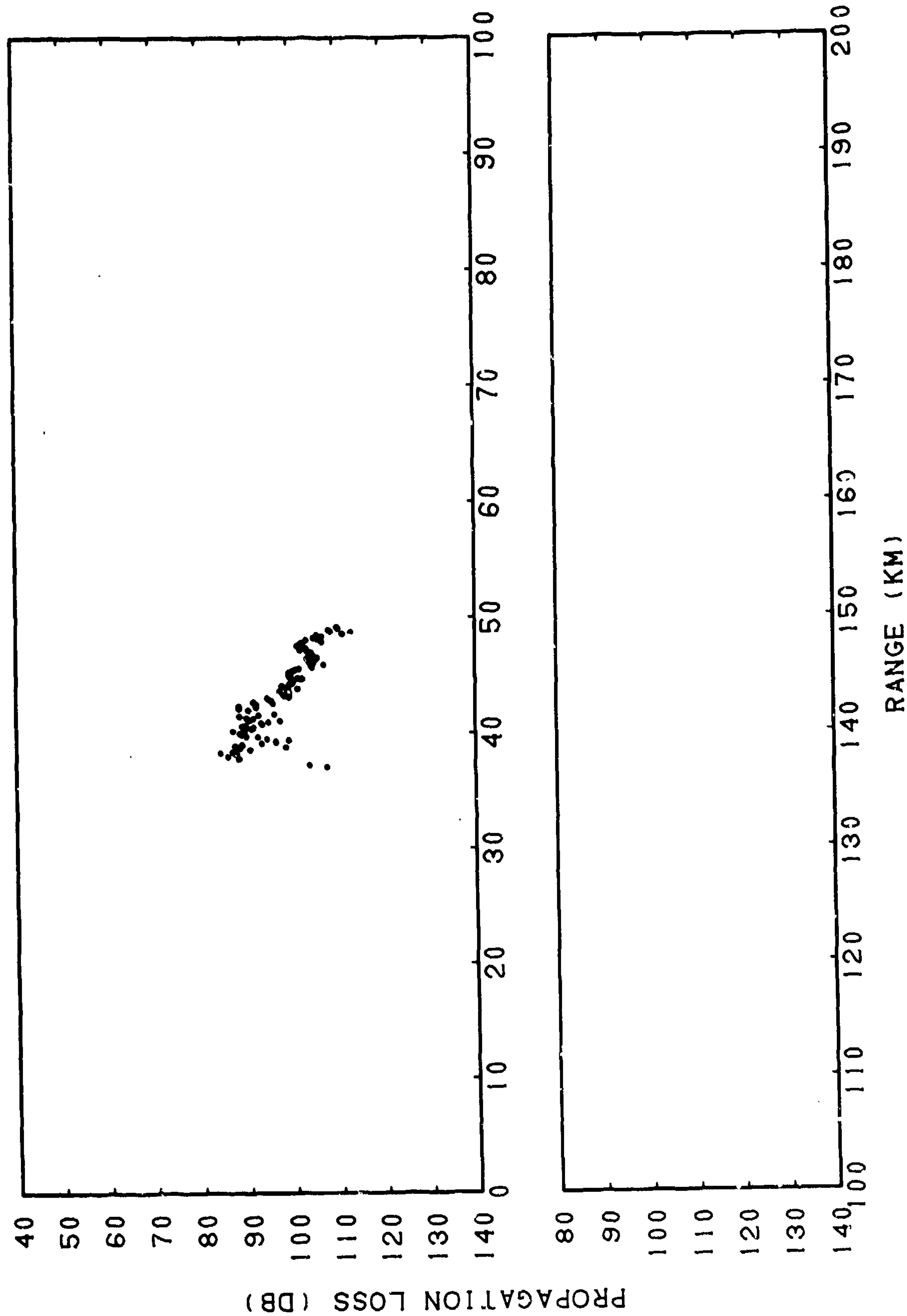
CONFIDENTIAL

(C) Figure IIIF-15e. RAYMODE Incoherent Station 3 Run 43, Source Depth = 20 Feet, Receiver Depth = 260 Feet

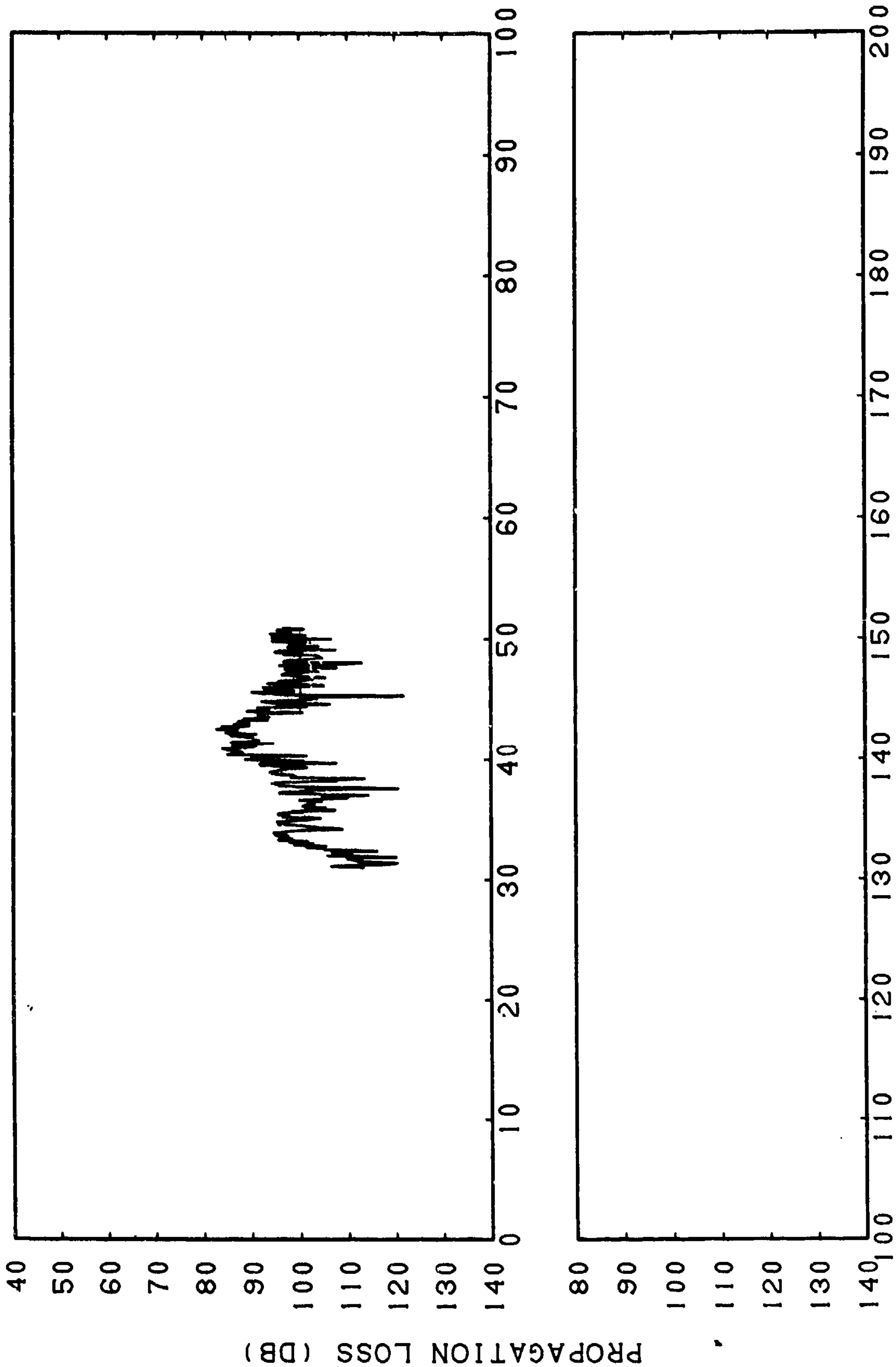


CONFIDENTIAL

(C) Figure IIIF-15f. RAYMODE Incoherent Station 3 Run 43, Source Depth = 20 Feet, Receiver Depth = 260 Feet, Subtracted from Station 3 Run 43, Source Depth = 20 Feet, Receiver Depth = 260 Feet

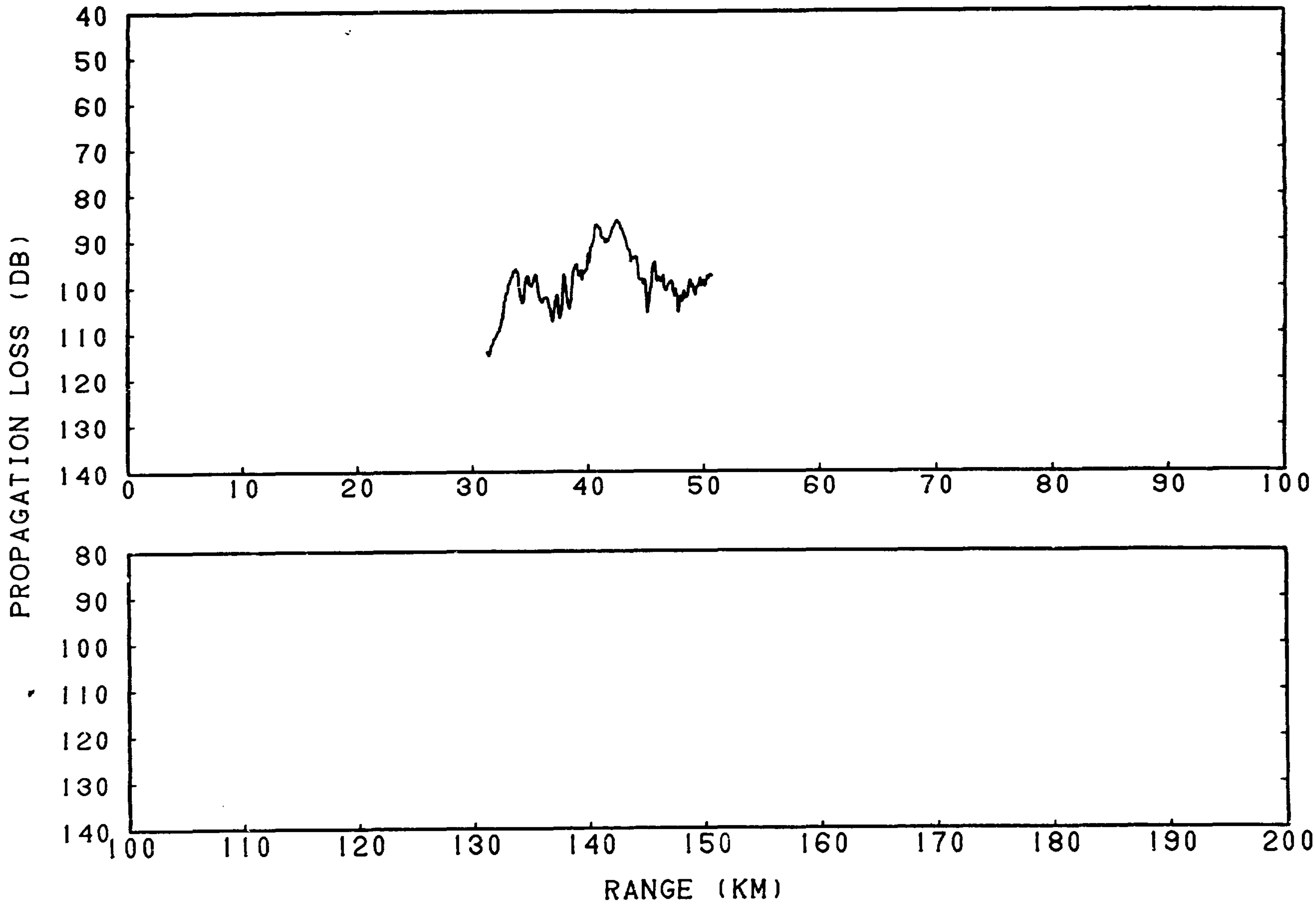


(C) Figure IIIF-16a. Station 3 Run 43, Source Depth = 20 Feet, Receiver Depth = 535 Feet



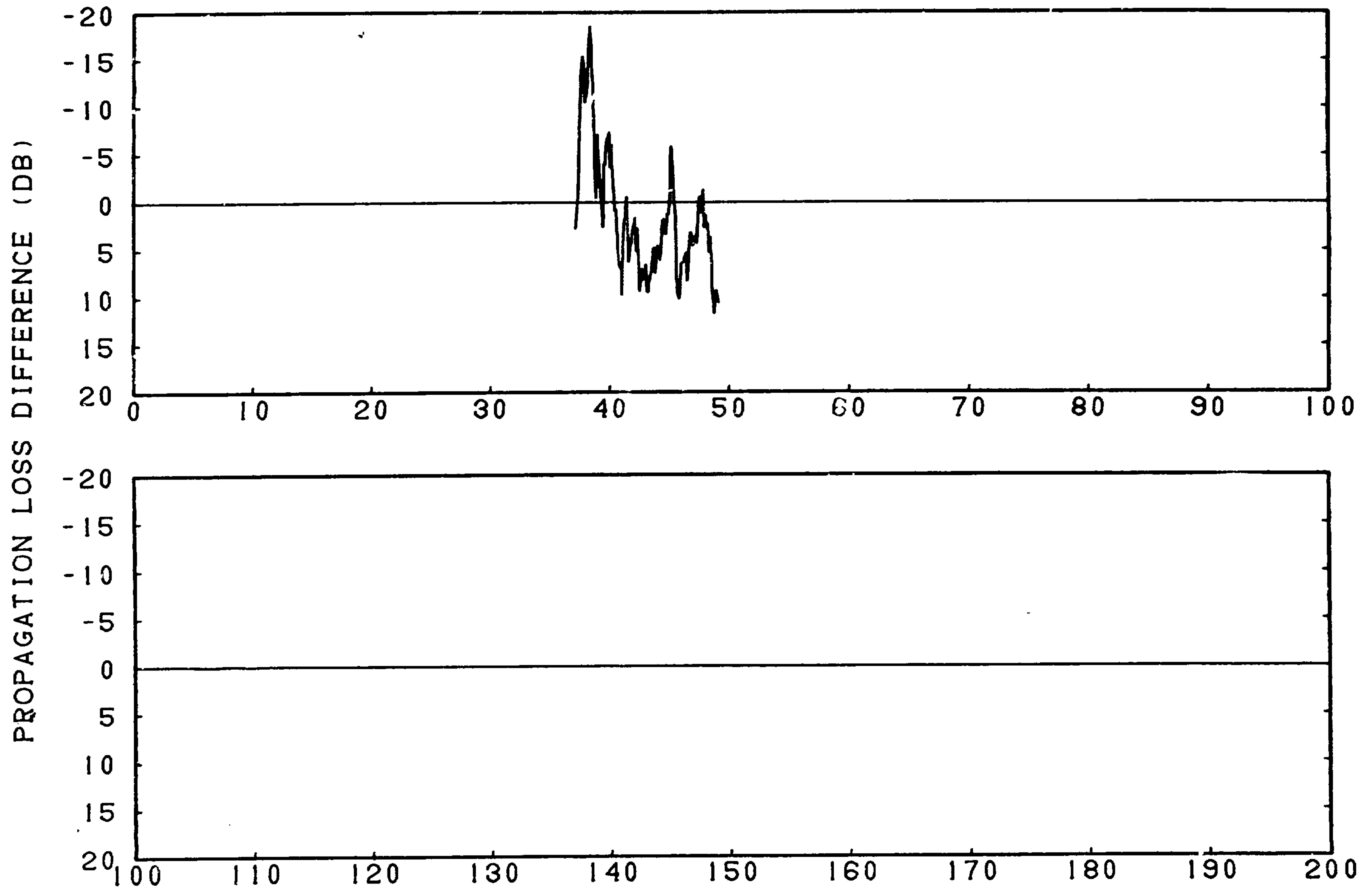
CONFIDENTIAL

(C) Figure IIIF-16b. Raymode Coherent Station 3 Run 43, Source Depth = 20 Feet, Receiver Depth = 535 Feet



CONFIDENTIAL

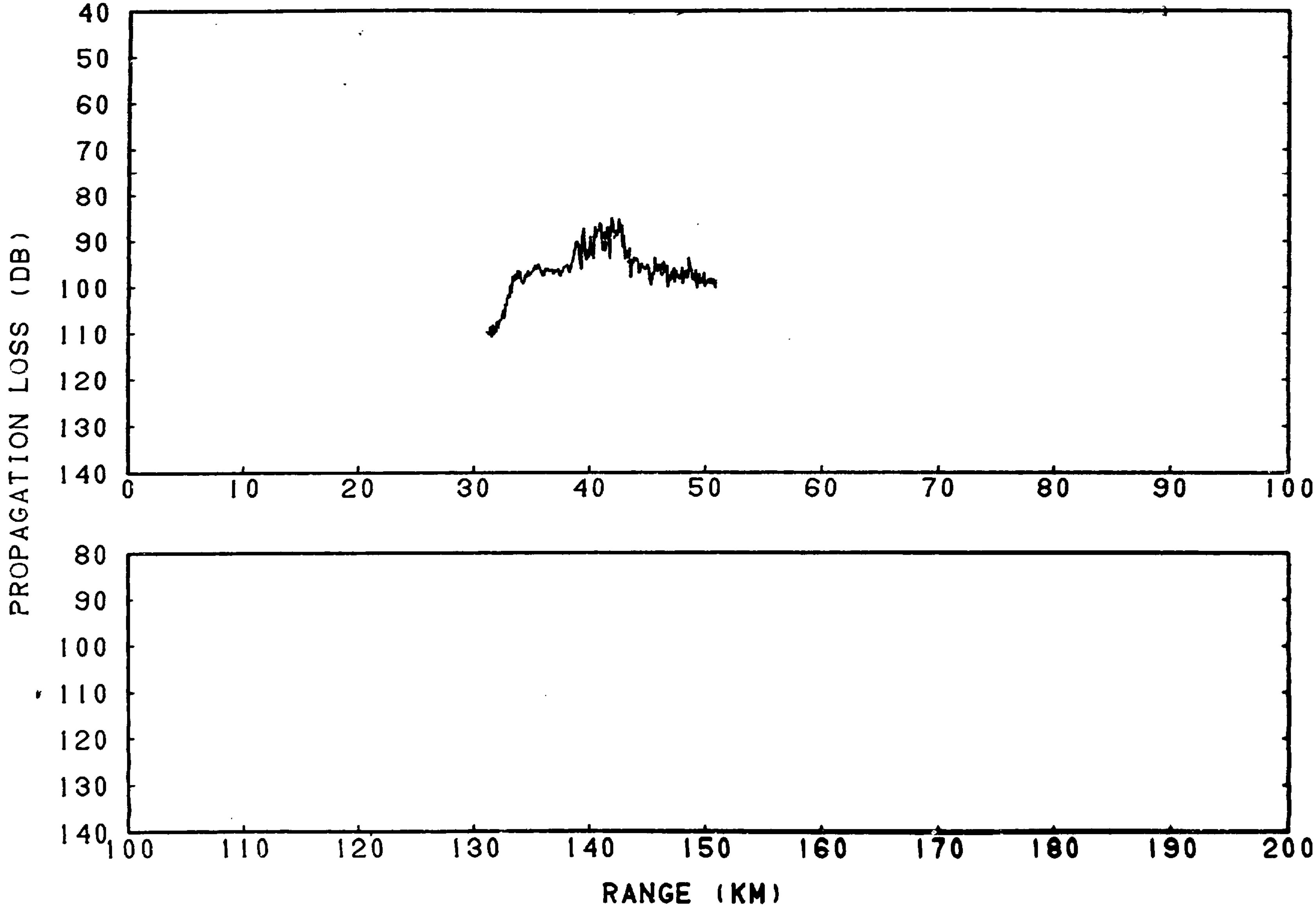
(C) Figure IIIF-16c. Raymode Coherent Station 3 Run 43, Source Depth = 20 Feet, Receiver Depth = 535 Feet, Sliding Averages of 5 Points (0.39 Kilometer)



CONFIDENTIAL

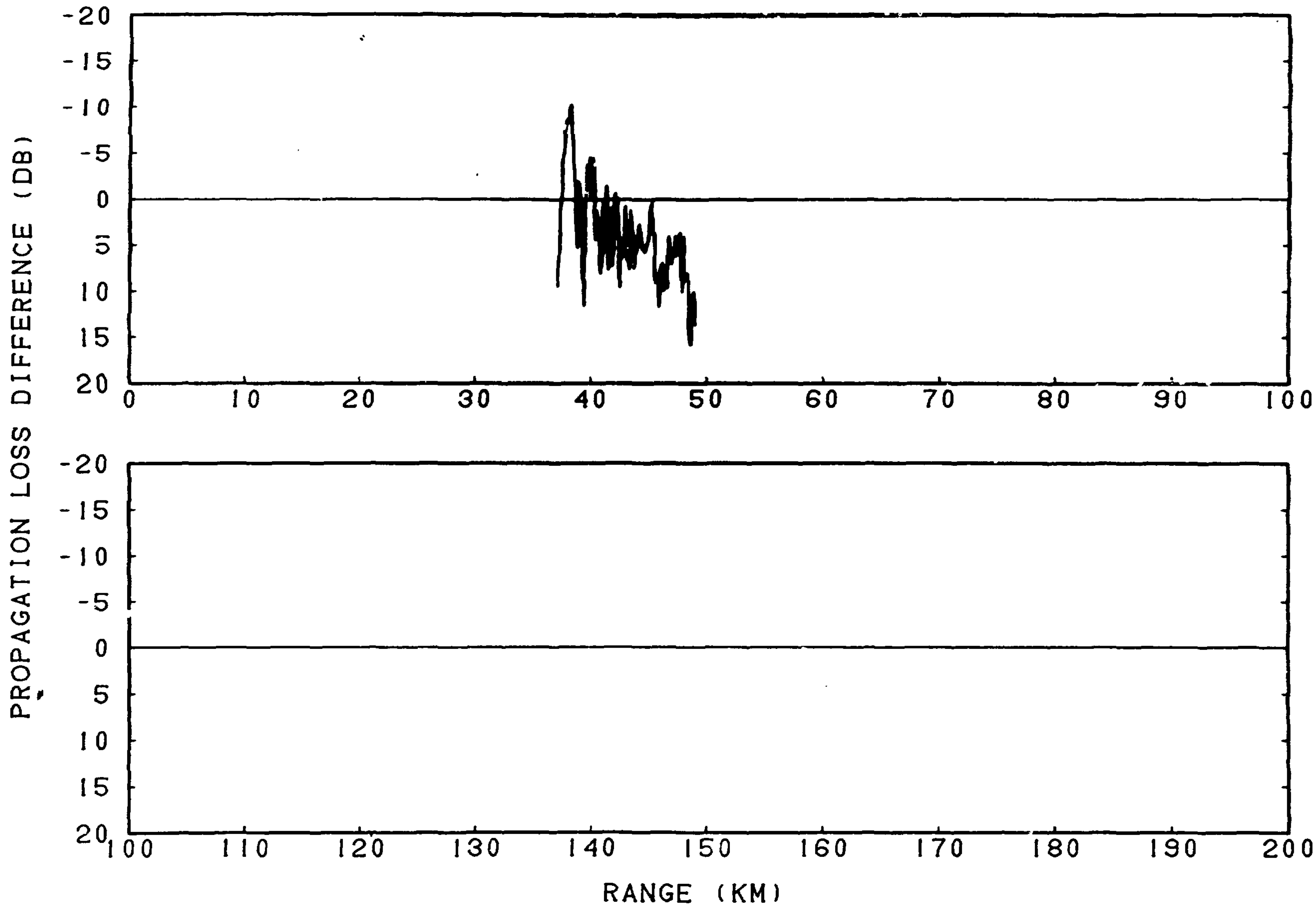
(C) Figure IIIF-16d. Smoothed Raymode Coherent Station 3 Run 43, Source Depth = 20 Feet, Receiver Depth = 535 Feet, Subtracted from Station 3 Run 43, Source Depth = 20 Feet, Receiver Depth = 535 Feet

CONFIDENTIAL



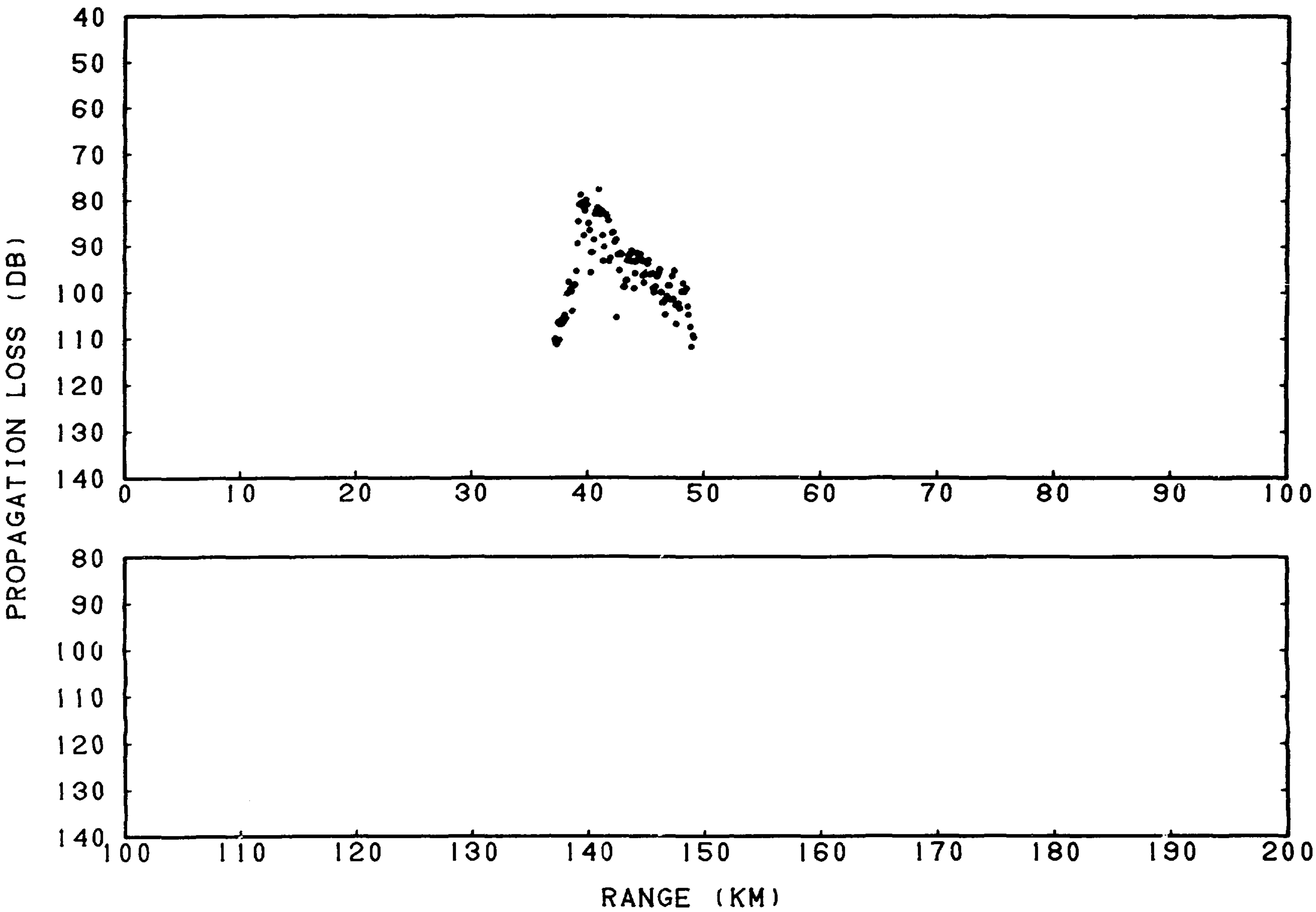
CONFIDENTIAL

(C) Figure IIIF-16e. **Raymode Incoherent Station 3 Run 43, Source Depth = 20 Feet, Receiver Depth = 535 Feet**



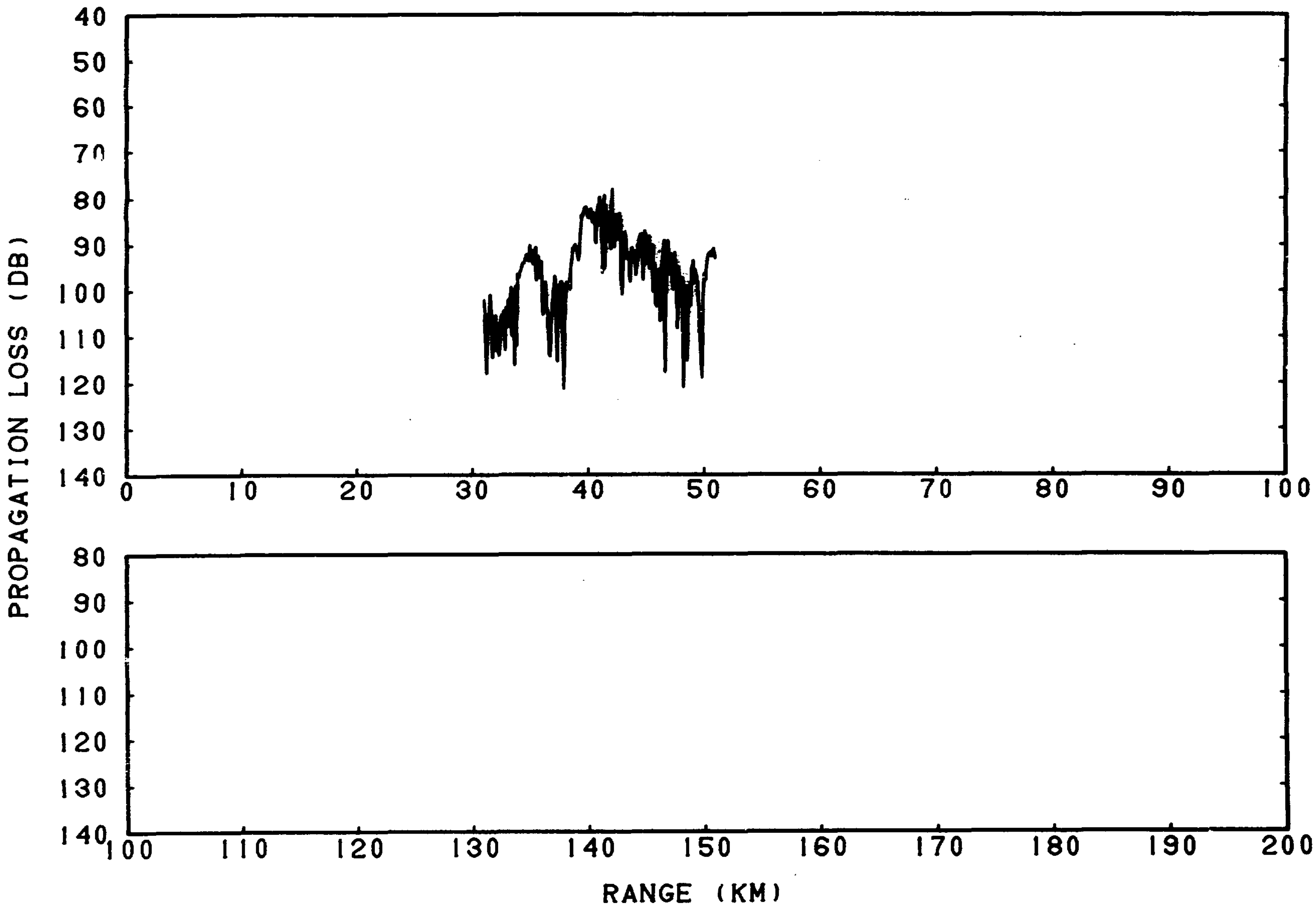
CONFIDENTIAL

(C) Figure IIIF-16f. Raymode Incoherent Station 3 Run 43, Source Depth = 20 Feet, Receiver Depth = 535 Feet, Subtracted from Station 3 Run 43, Source Depth = 20 Feet, Receiver Depth = 535 Feet



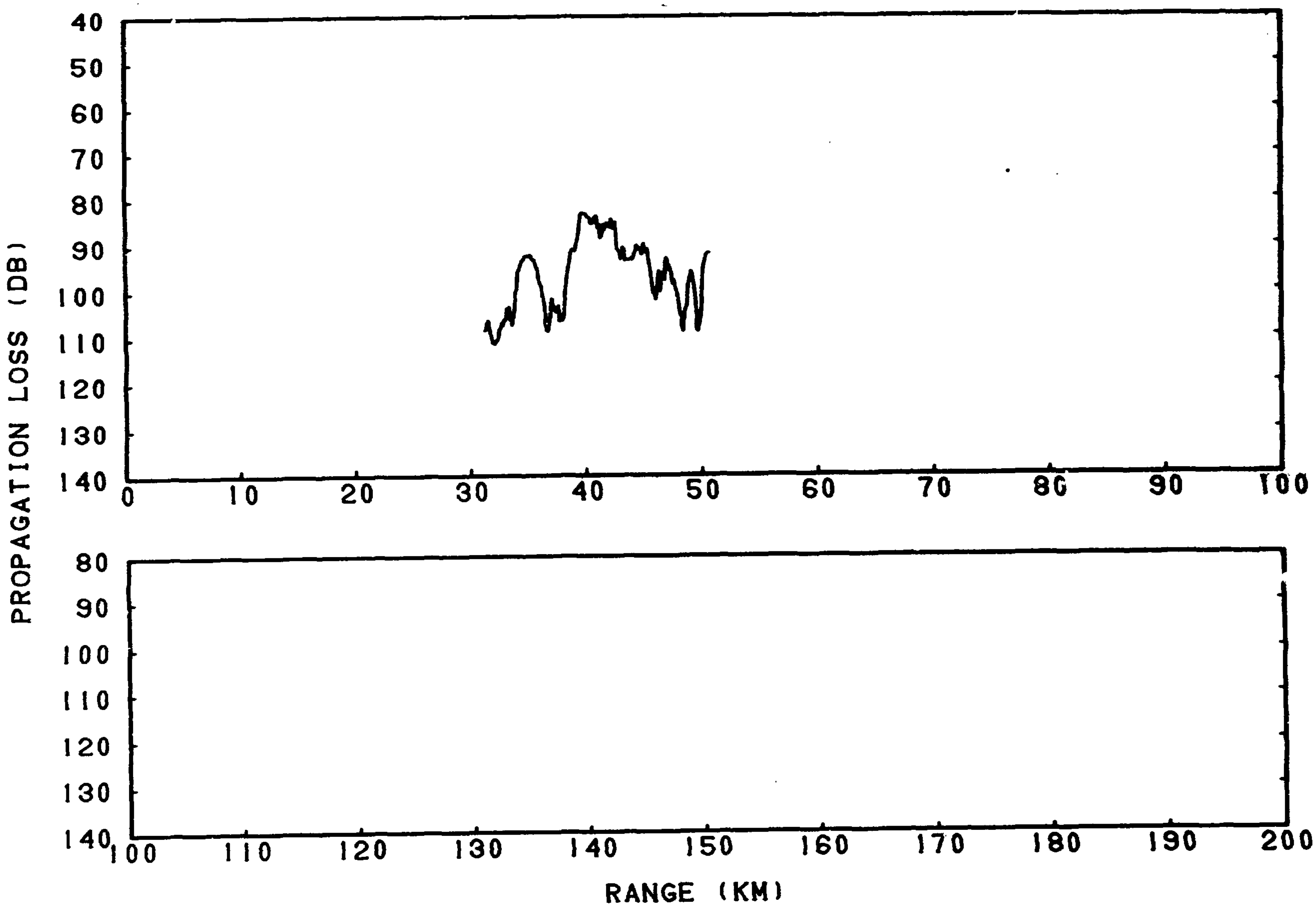
CONFIDENTIAL

(C) Figure IIIF-17a. Station 3 Run 103, Source Depth = 20 Feet, Receiver Depth = 60 Feet



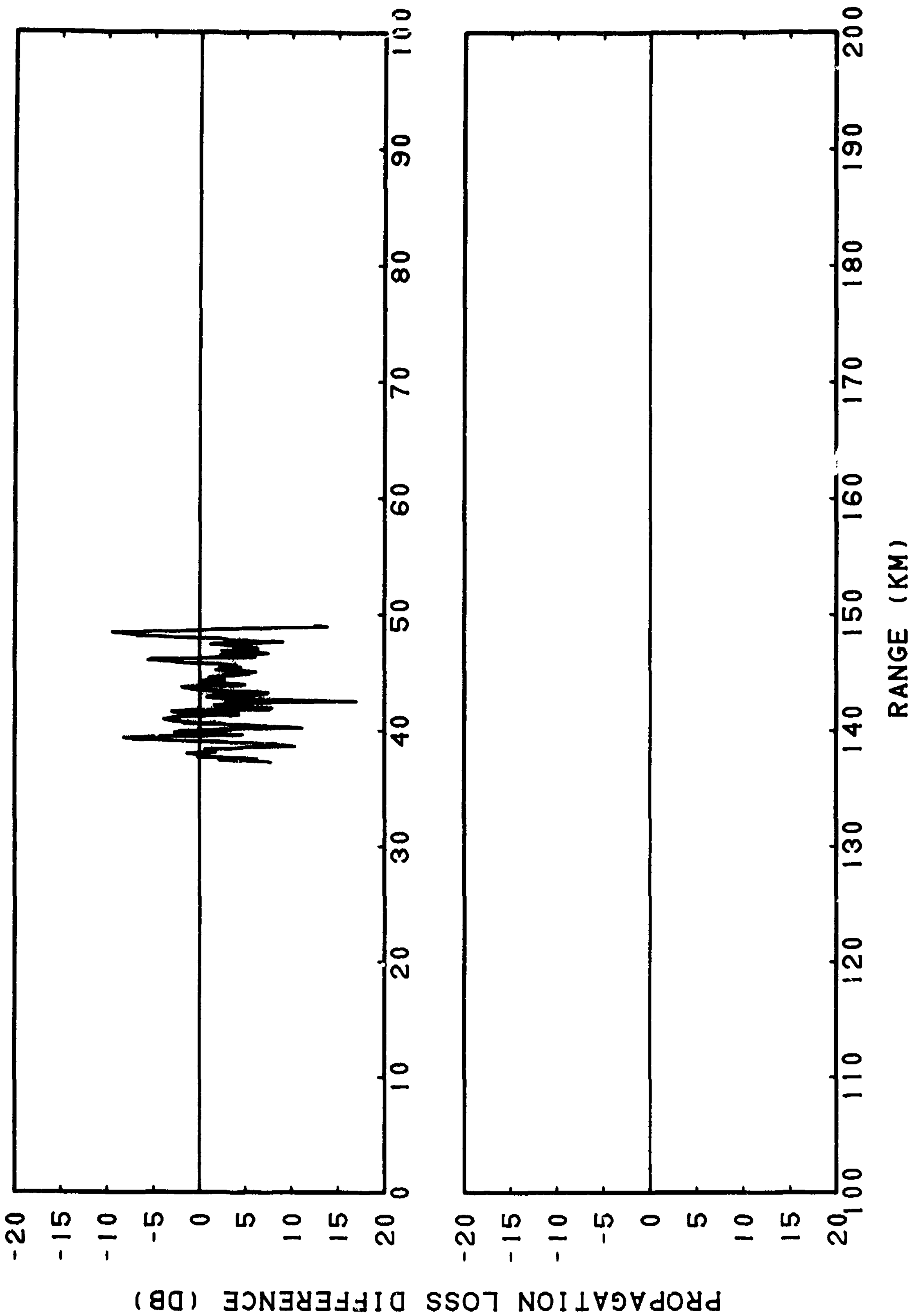
CONFIDENTIAL

(C) Figure IIIF-17b. RAYMODE Coherent Station 3 Run 103, Source Depth = 20 Feet, Receiver Depth = 60 Feet



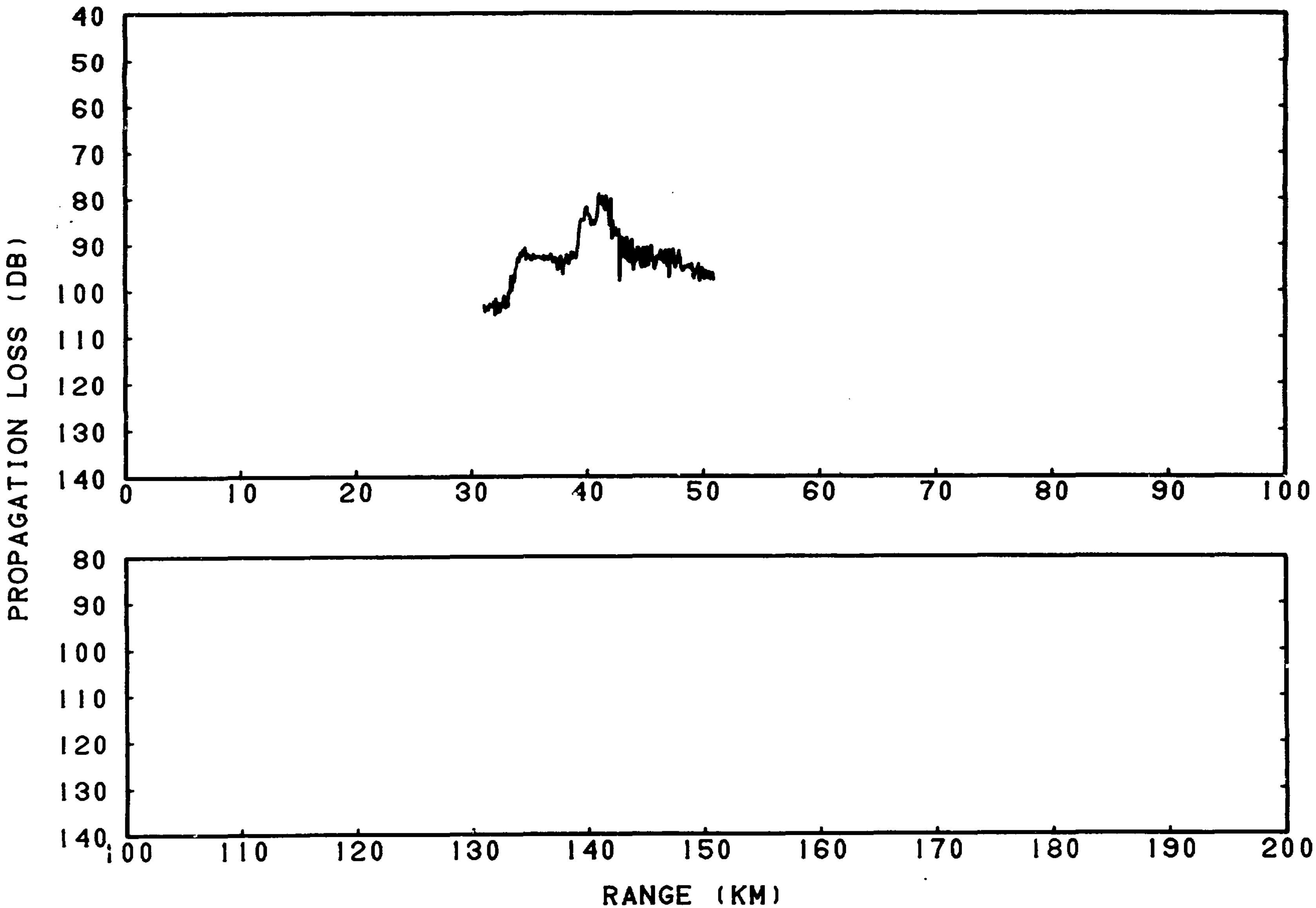
CONFIDENTIAL

(C) Figure IIIF-17c. RAYMODE Coherent Station 3 Run 103, Source Depth = 20 Feet, Receiver Depth = 60 Feet, Sliding Averages of 5 Points (0.39 Kilometer)



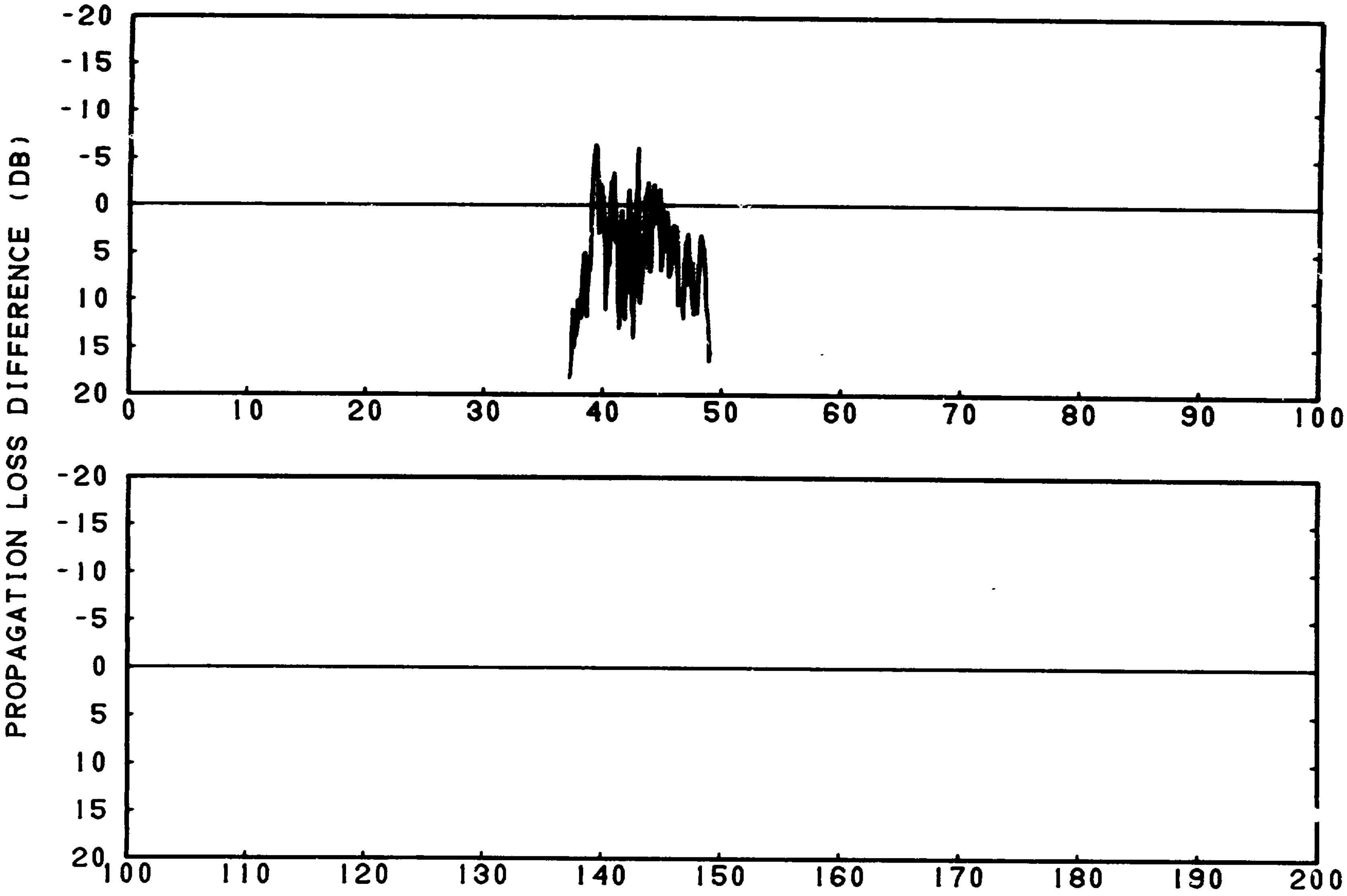
CONFIDENTIAL

(C) Figure IIIF-17d. Smoothed RAYMODE Coherent Station 3 Run 103, Source Depth = 20 Feet, Receiver Depth = 60 Feet, Subtracted from Station 3 Run 103, Source Depth = 20 Feet, Receiver Depth = 60 Feet



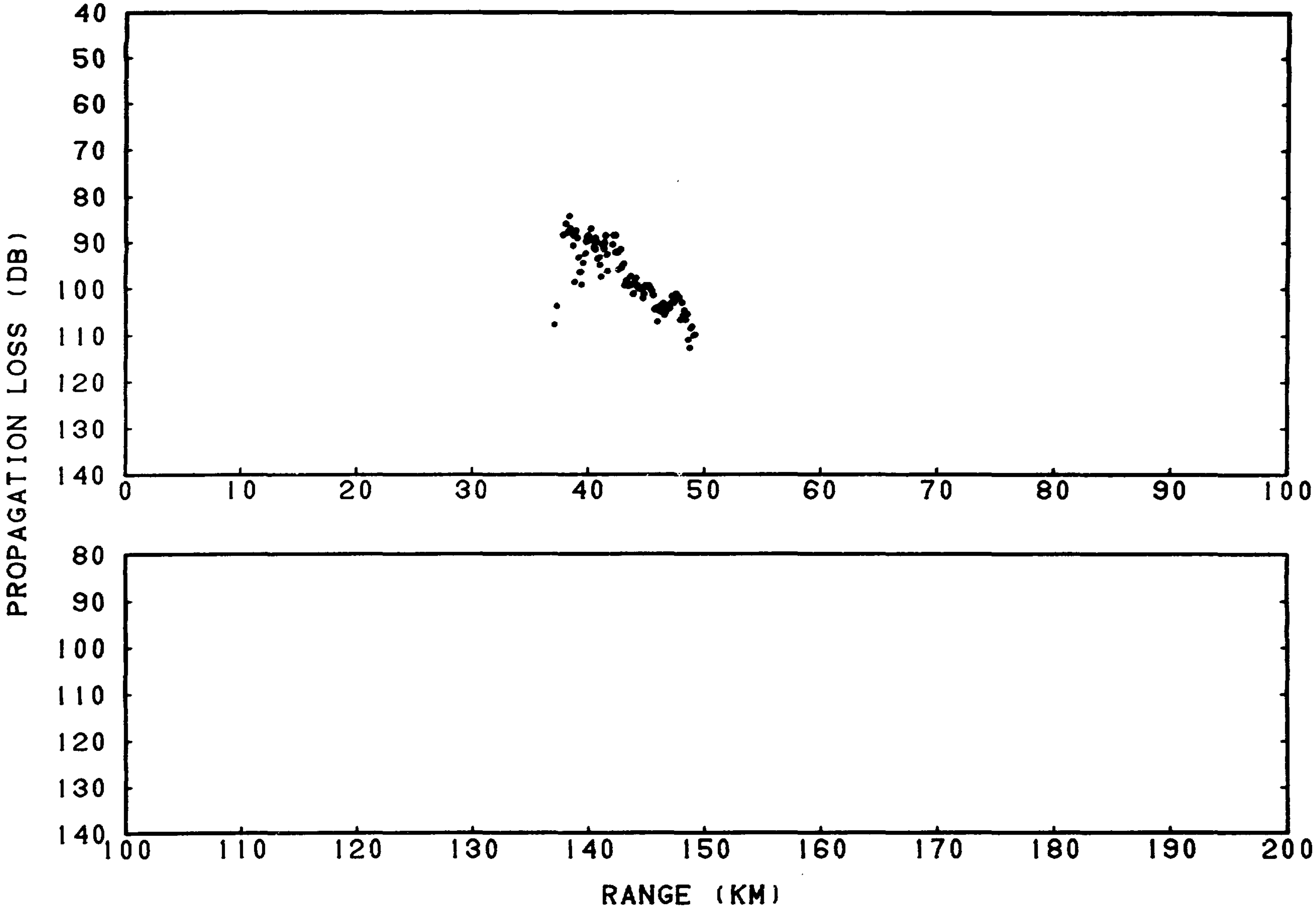
CONFIDENTIAL

(C) Figure IIIF-17e. RAYMODE Incoherent Station 3 Run 103, Source Depth = 20 Feet, Receiver Depth = 60 Feet



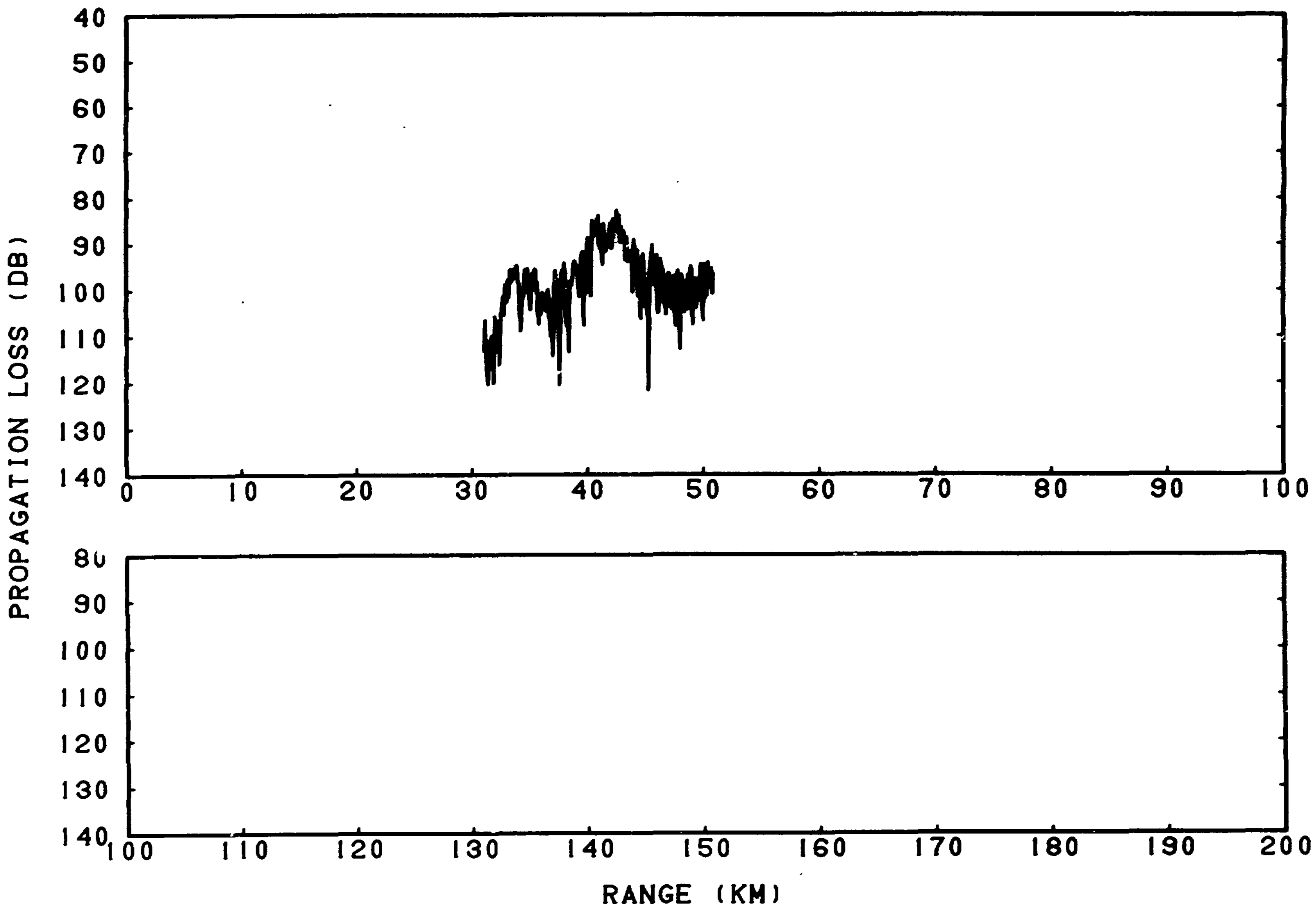
CONFIDENTIAL

(C) Figure IIIF-17f. RAYMODE Incoherent Station 3 Run 103, Source Depth = 20 Feet, Receiver Depth = 60 Feet, Subtracted from Station 3 Run 103, Source Depth = 20 Feet, Receiver Depth = 60 Feet



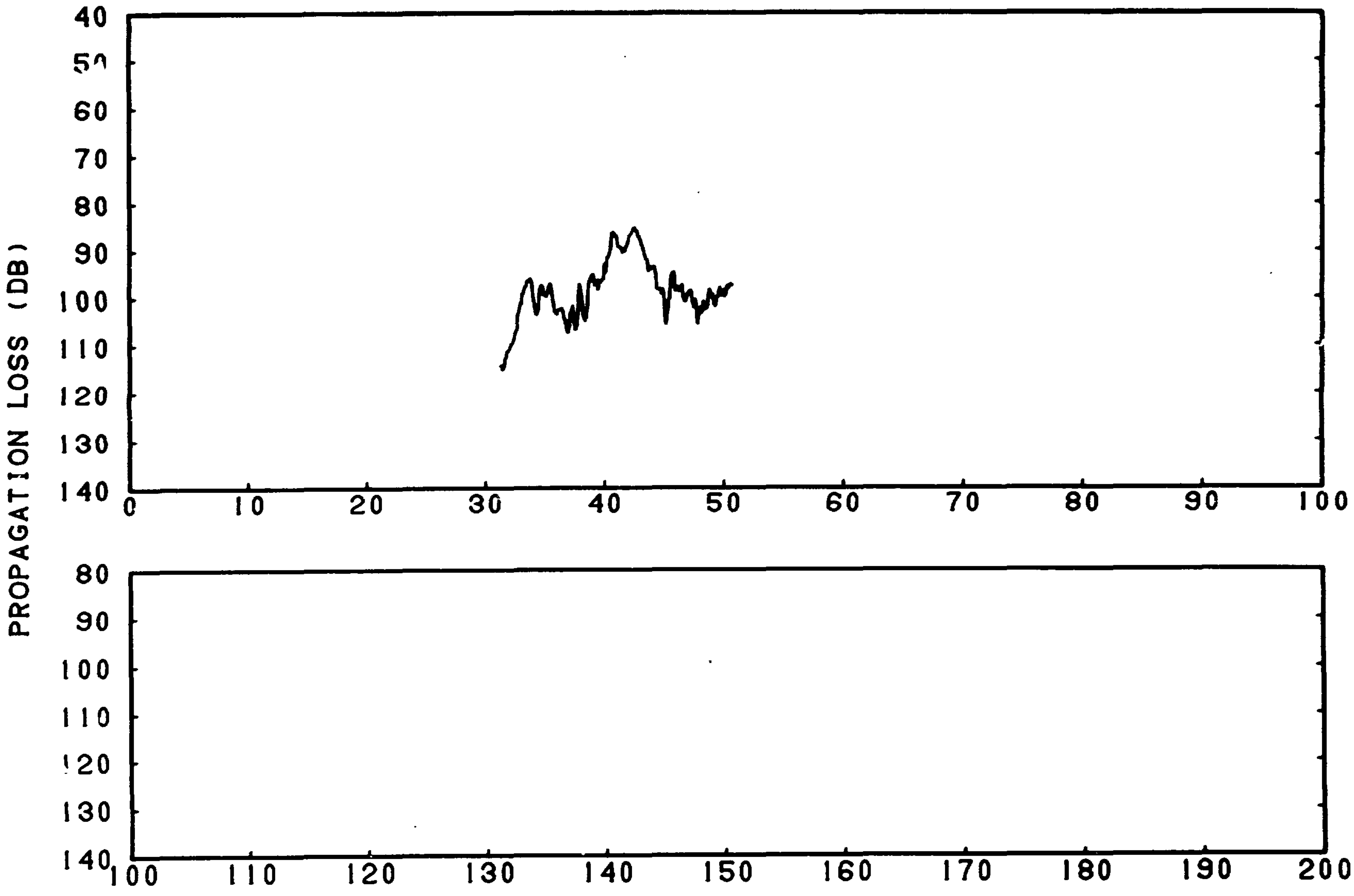
CONFIDENTIAL

(C) Figure IIIF-18a. Station 3 Run 93, Source Depth = 20 Feet, Receiver Depth = 535 Feet



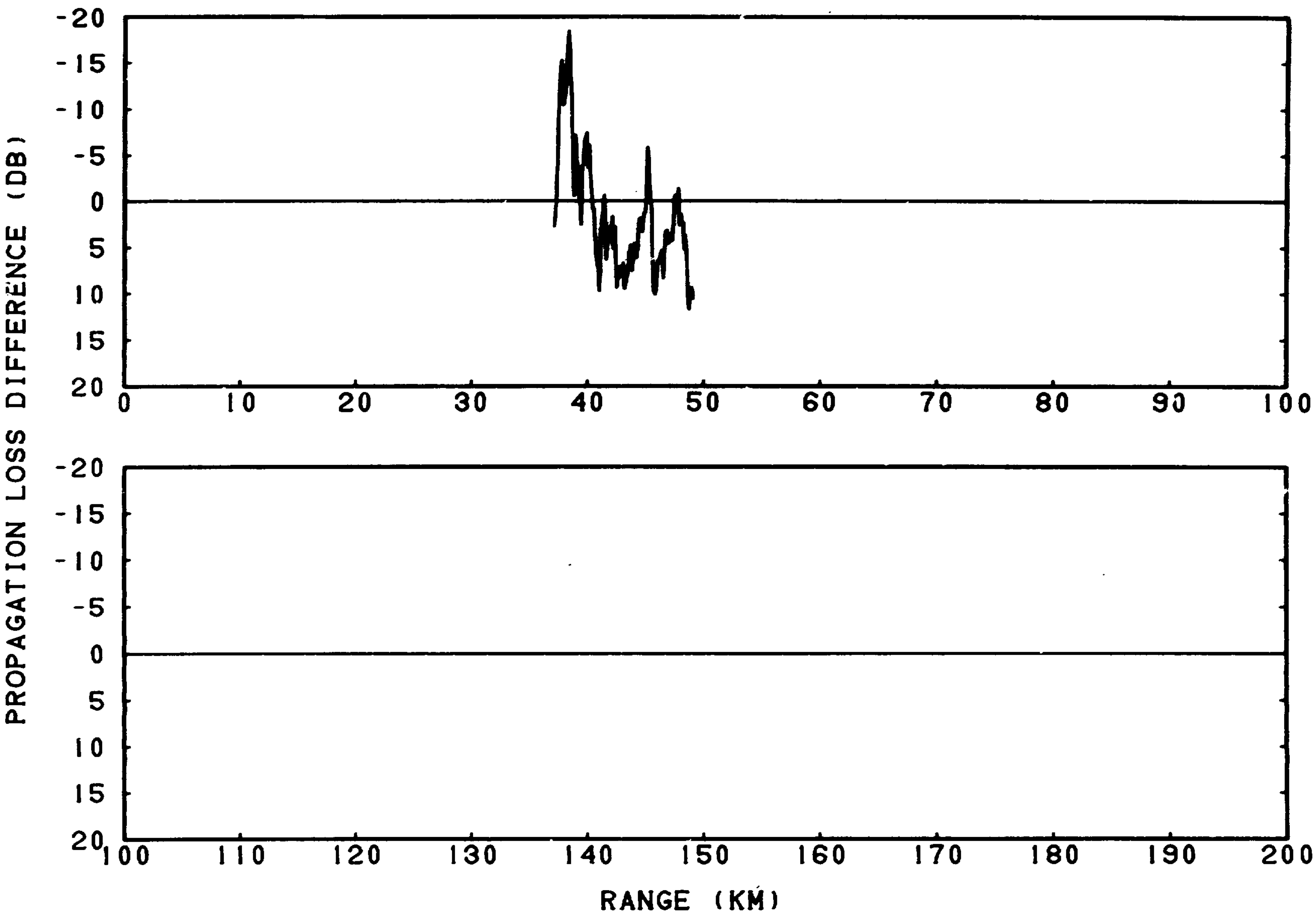
CONFIDENTIAL

(C) Figure IIIF-18b. RAYMODE Coherent Station 3 Run 93, Source Depth = 20 Feet, Receiver Depth = 535 Feet



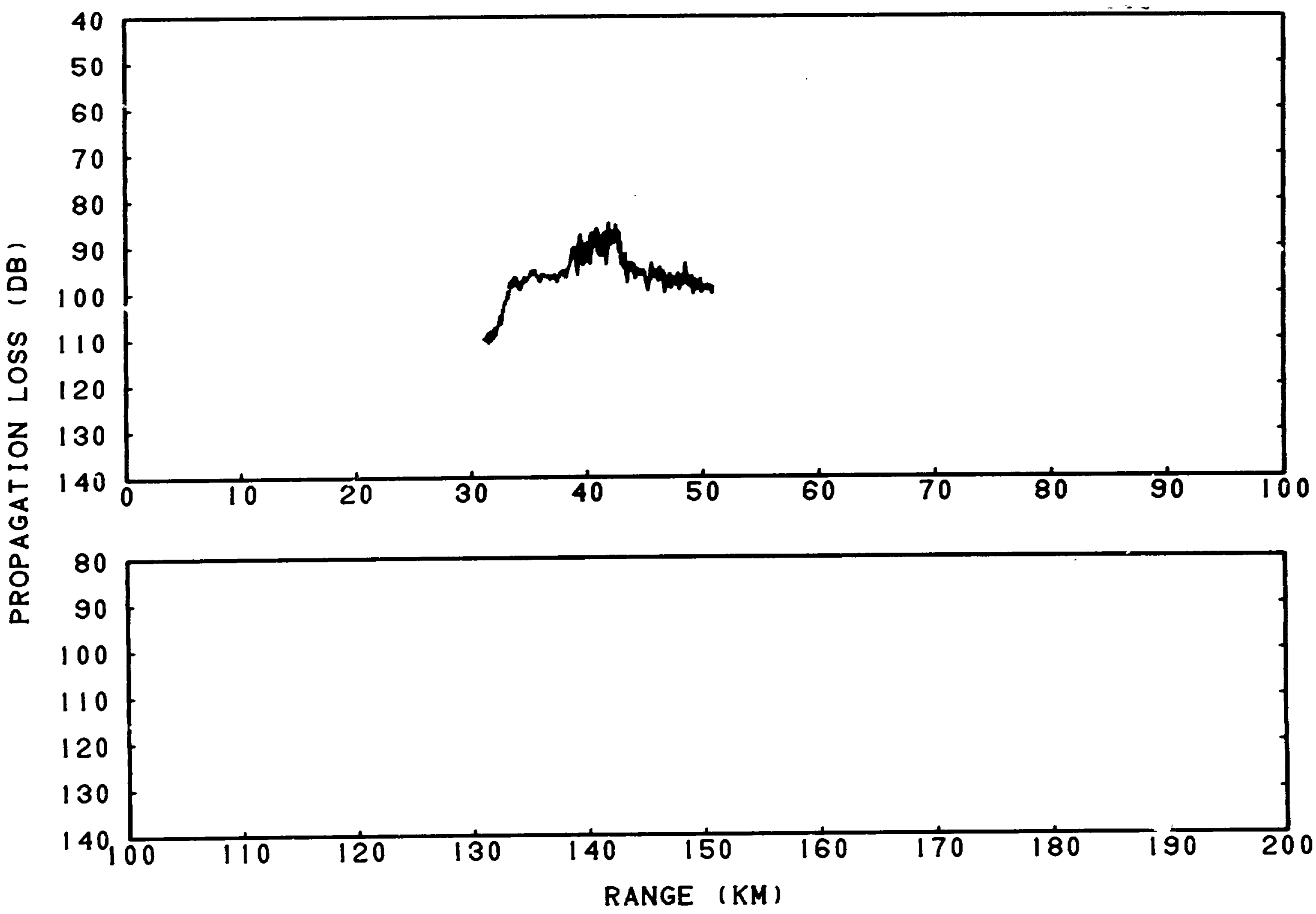
CONFIDENTIAL

(C) Figure IIIF-18c. RAYMODE Coherent Station 3 Run 93, Source Depth = 20 Feet, Receiver Depth = 535 Feet, Sliding Averages of 5 Points (0.39 Kilometer)



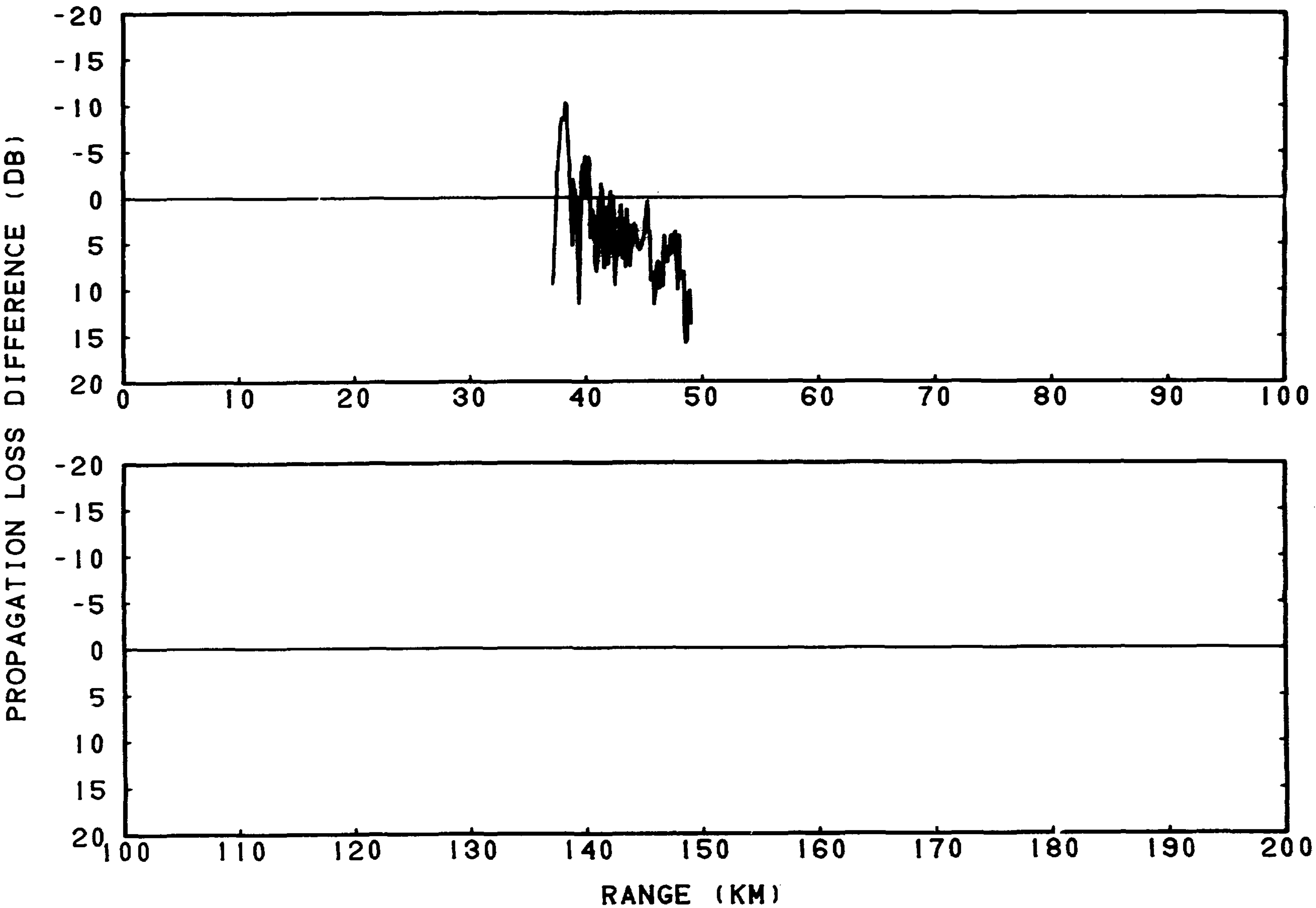
CONFIDENTIAL

(C) Figure IIIF-18d. Smoothed RAYMODE Coherent Station 3 Run 93, Source Depth = 20 Feet, Receiver Depth = 535 Feet, Subtracted from Station 3 Run 93, Source Depth = 20 Feet, Receiver Depth = 535 Feet



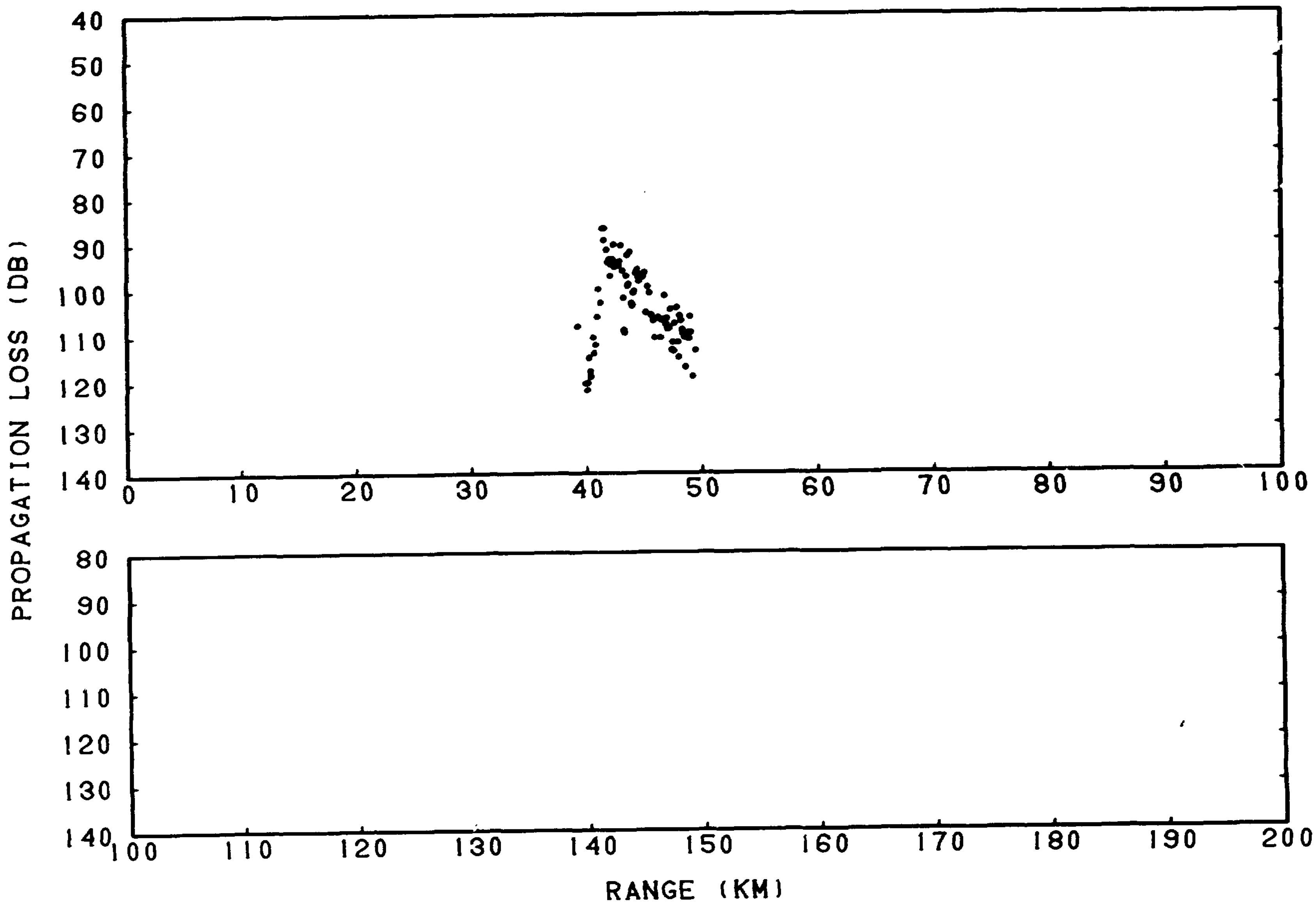
CONFIDENTIAL

(C) Figure IIIF-18e. RAYMODE Incoherent Station 3 Run 93, Source Depth = 20 Feet, Receiver Depth = 535 Feet



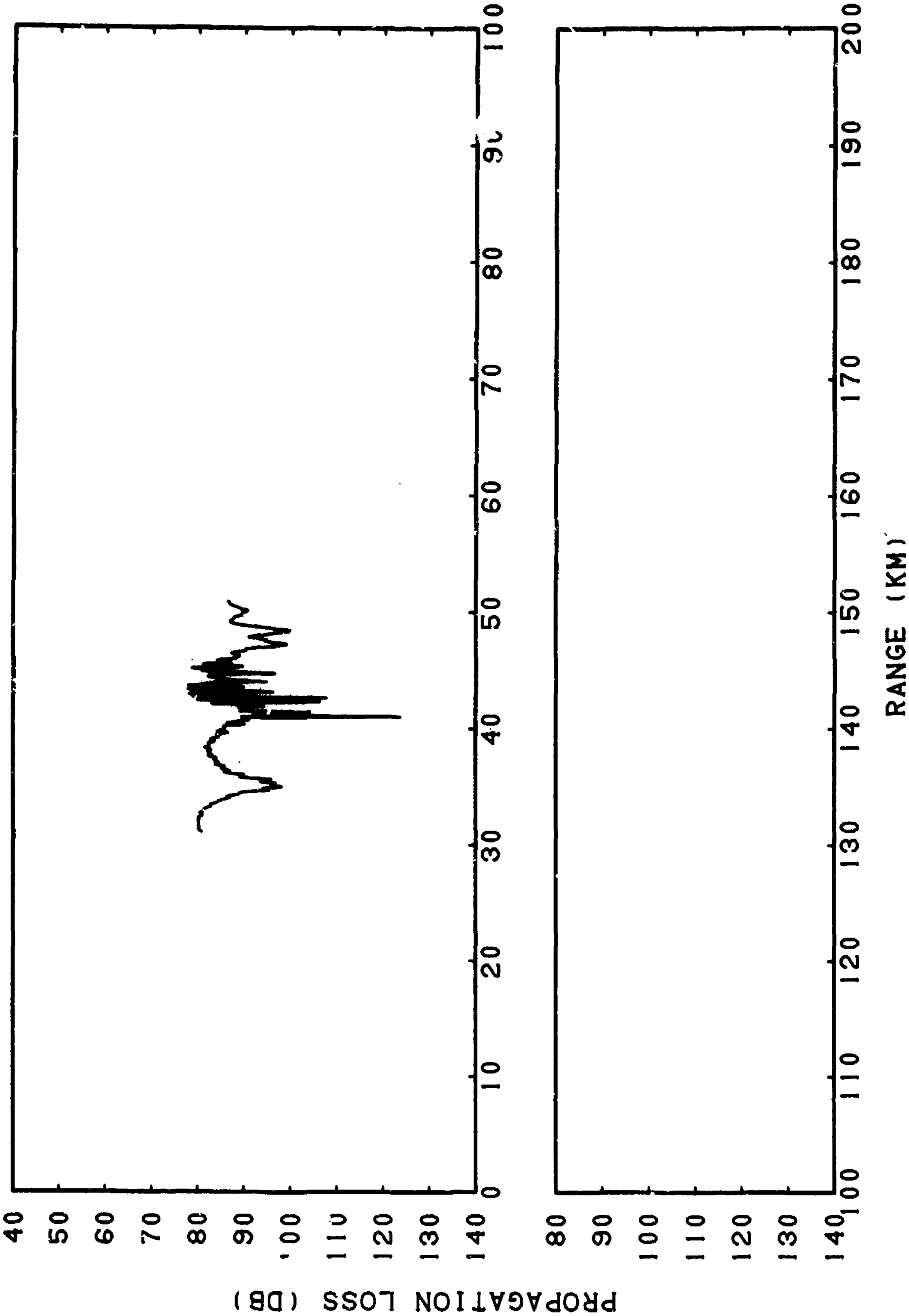
CONFIDENTIAL

(C) Figure IIIF-18f. RAYMODE Incoherent Station 3 Run 93, Source Depth = 20 Feet, Receiver Depth = 535 Feet, Subtracted from Station 3 Run 93, Source Depth = 20 Feet, Receiver Depth = 535 Feet



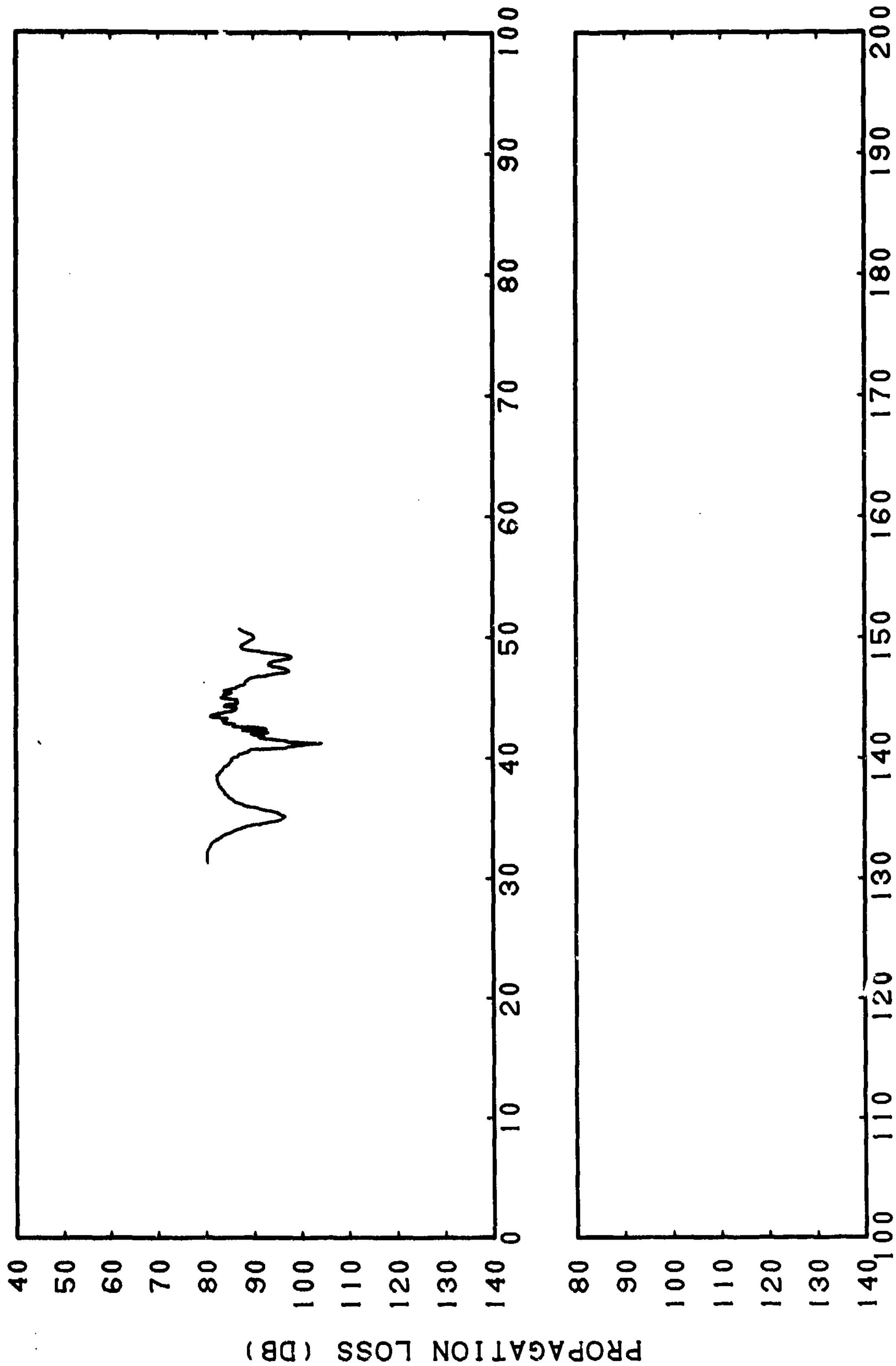
CONFIDENTIAL

(C) Figure IIIF-19a. Station 5 Run 43, Source Depth = 20 Feet, Receiver Depth = 60 Feet



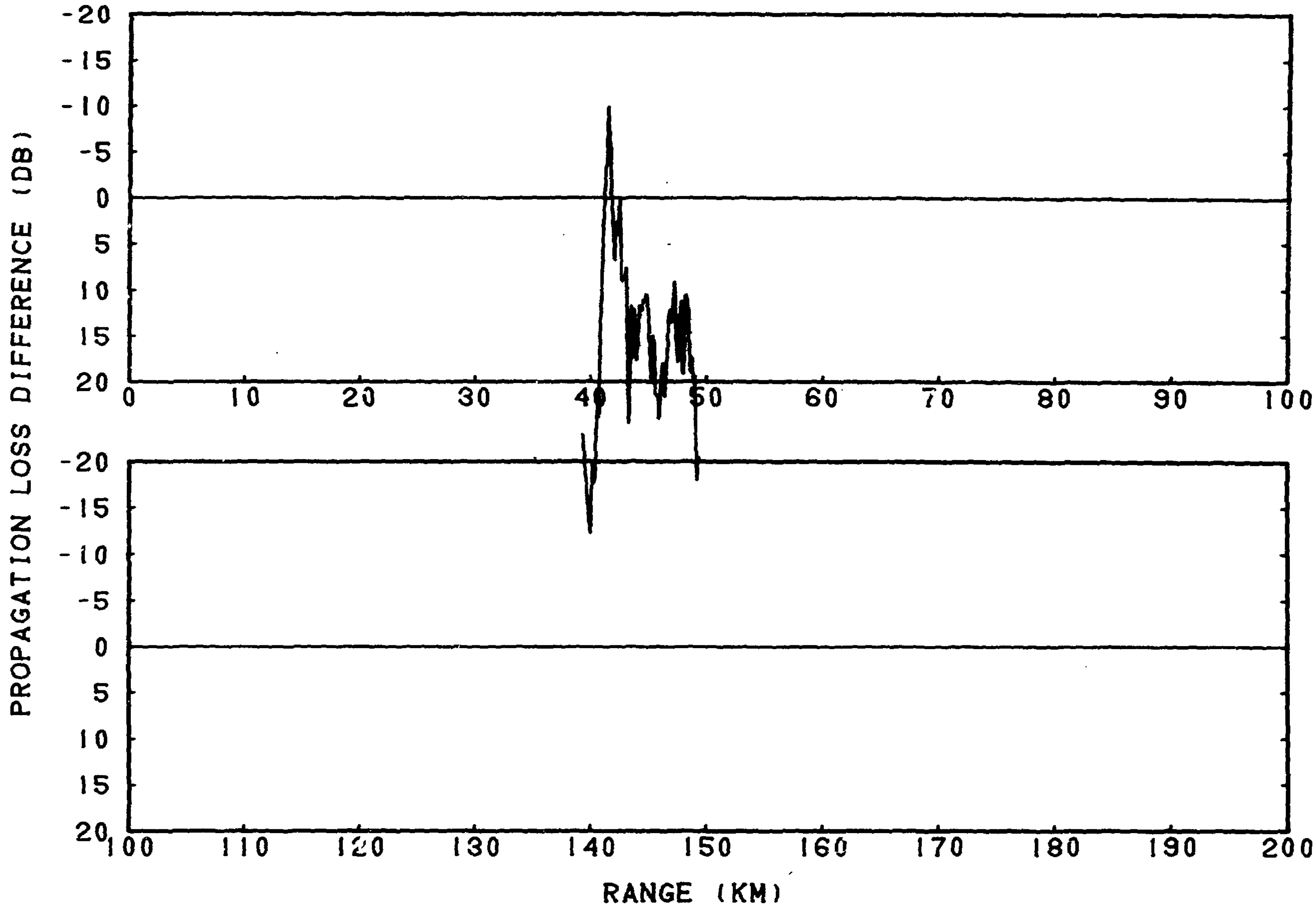
CONFIDENTIAL

(C) Figure IIIF-19b. RAYMODE Coherent Station 5 Run 43, Source Depth = 20 Feet, Receiver Depth = 60 Feet



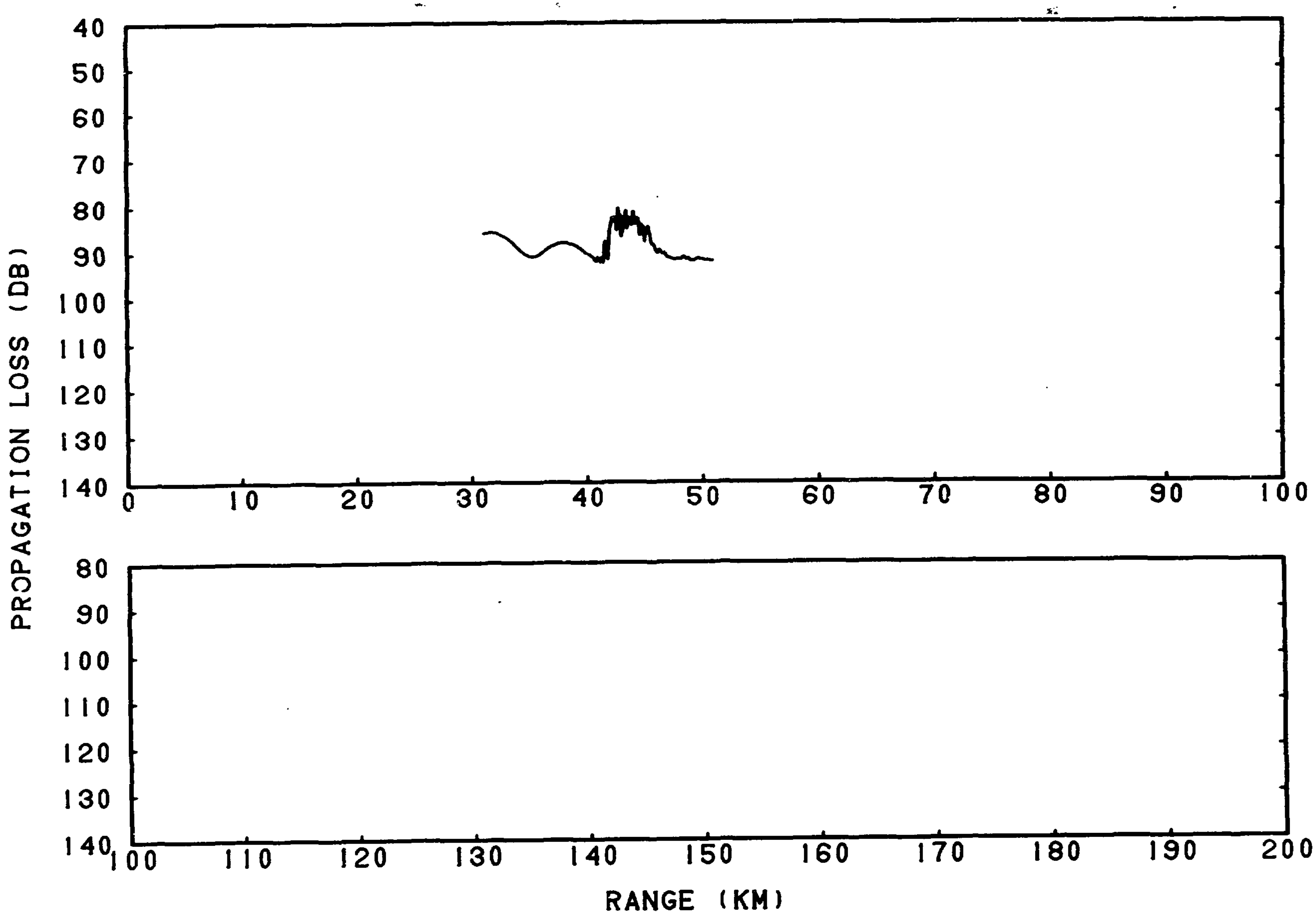
CONFIDENTIAL

(C) Figure IIIF-19c. RAYMODE Coherent Station 5 Run 43, Source Depth = 20 Feet, Receiver Depth = 60 Feet, Sliding Averages of 5 Points (0.39 Kilometer)



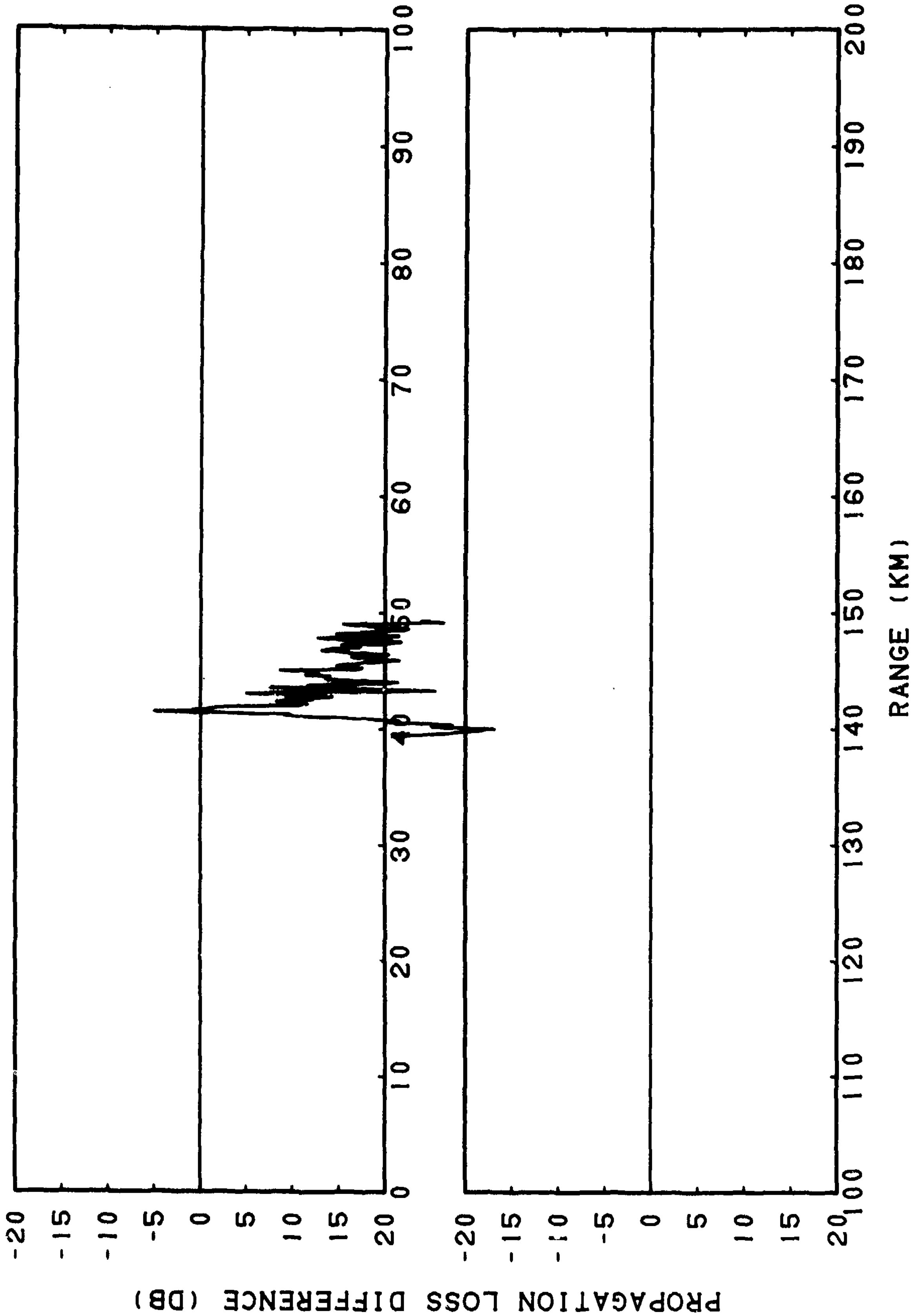
CONFIDENTIAL

(C) Figure IIIF-19d. Smoothed RAYMODE Coherent Station 5 Run 43, Source Depth = 20 Feet, Receiver Depth = 60 Feet, Subtracted from Station 5 Run 43, Source Depth = 20, Receiver Depth = 60 Feet



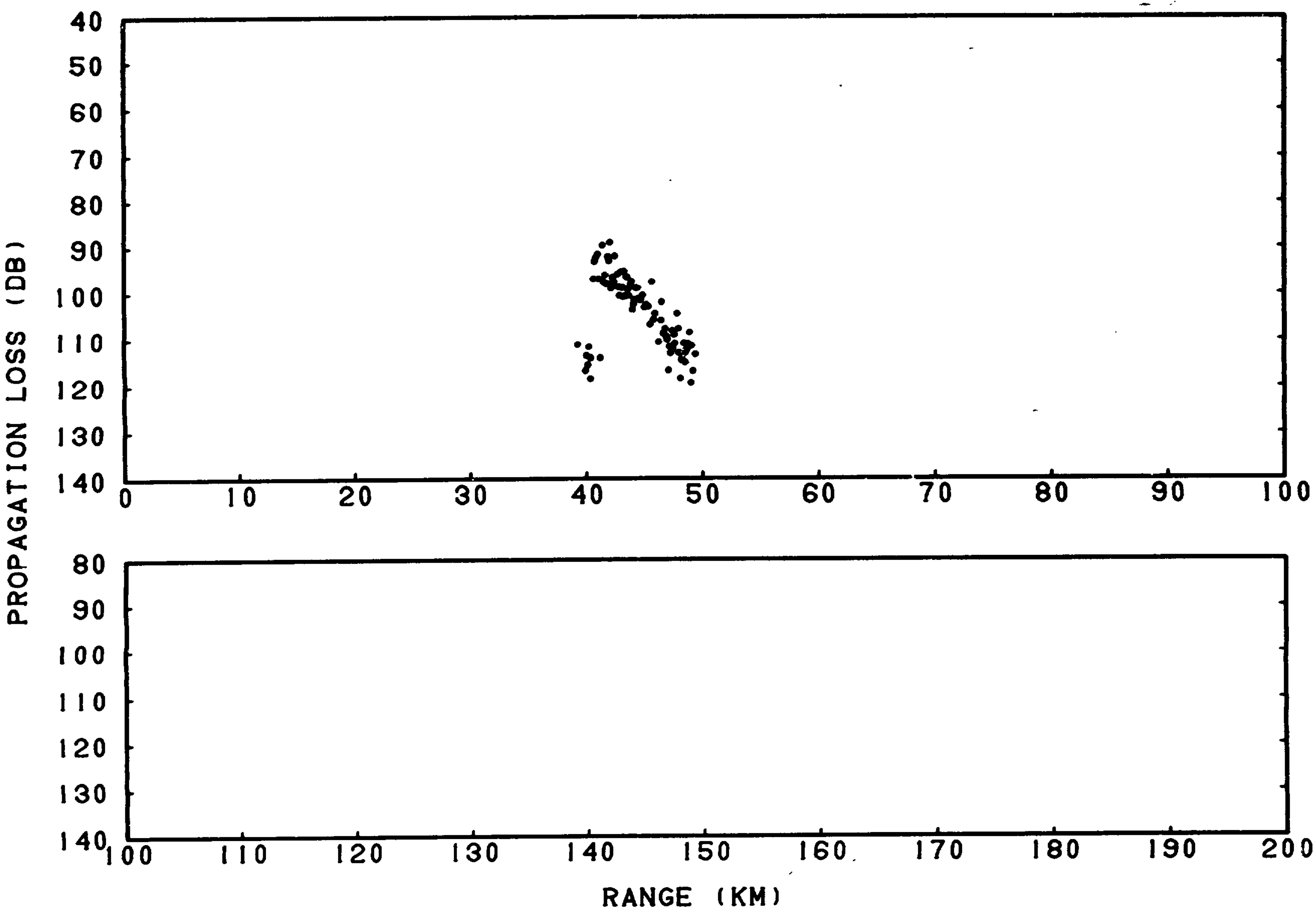
CONFIDENTIAL

(C) Figure IIIF-19e. RAYMODE Incoherent Station 5 Run 43, Source Depth = 20 Feet, Receiver Depth = 60 Feet



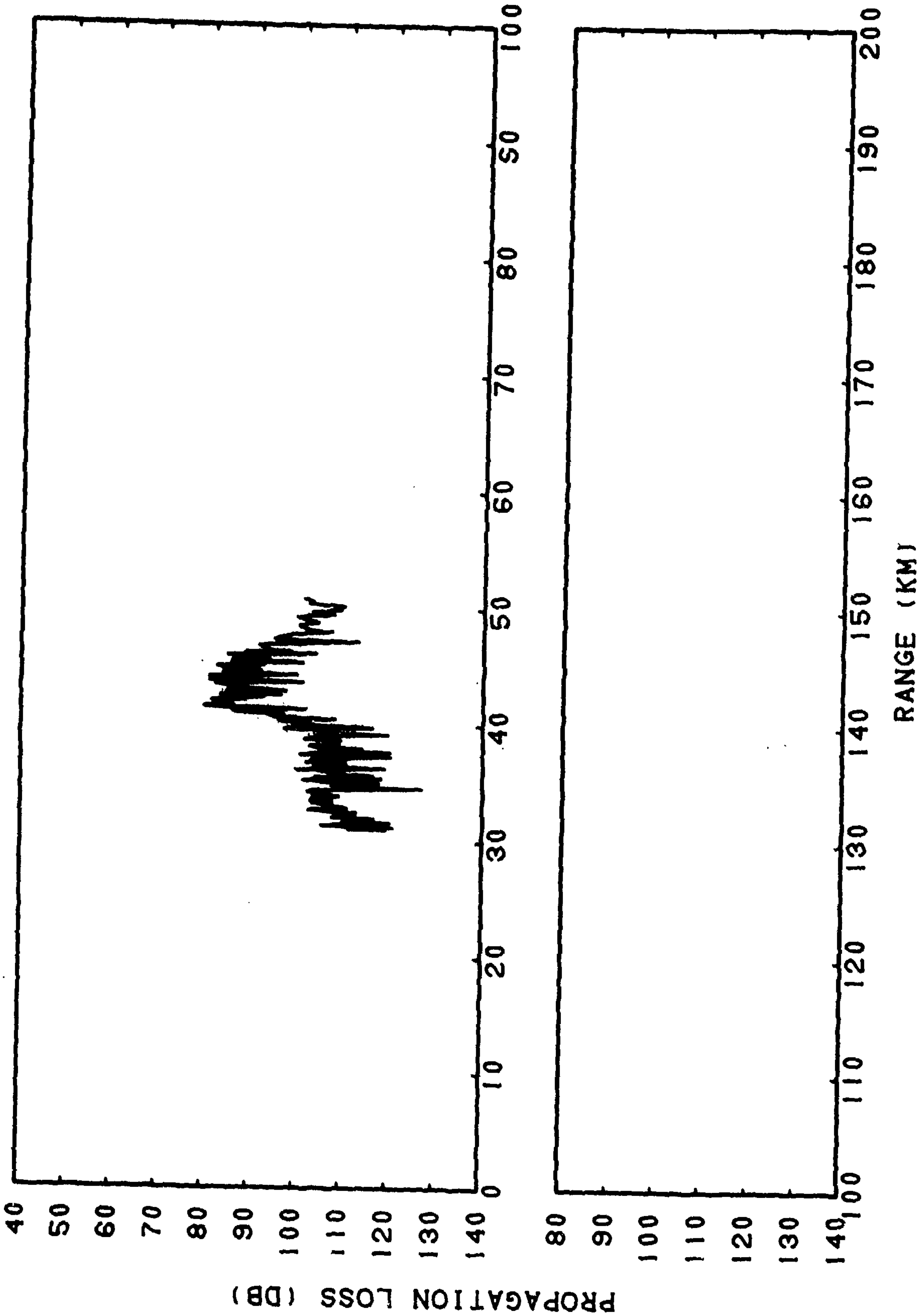
CONFIDENTIAL

(C) Figure IIIF-19f. RAYMODE Incoherent Station 5 Run 43, Source Depth = 20 Feet, Receiver Depth = 60 Feet, Subtracted from Station 5 Run 43, Source Depth = 20 Feet, Receiver Depth = 60 Feet



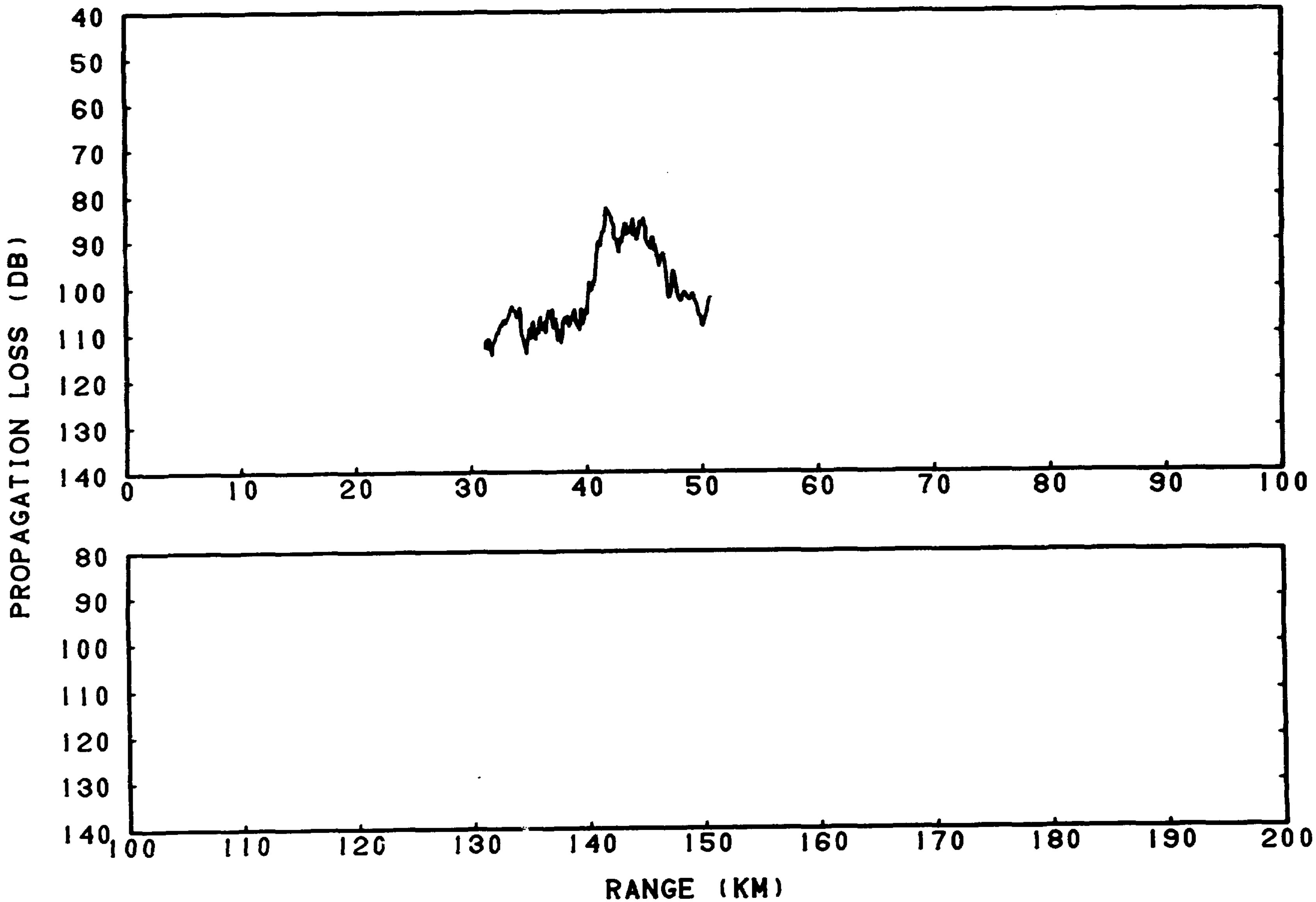
CONFIDENTIAL

(C) Figure IIIF-20a. RAYMODE Coherent Station 5 Run 43, Source Depth = 20 Feet, Receiver Depth = 260 Feet



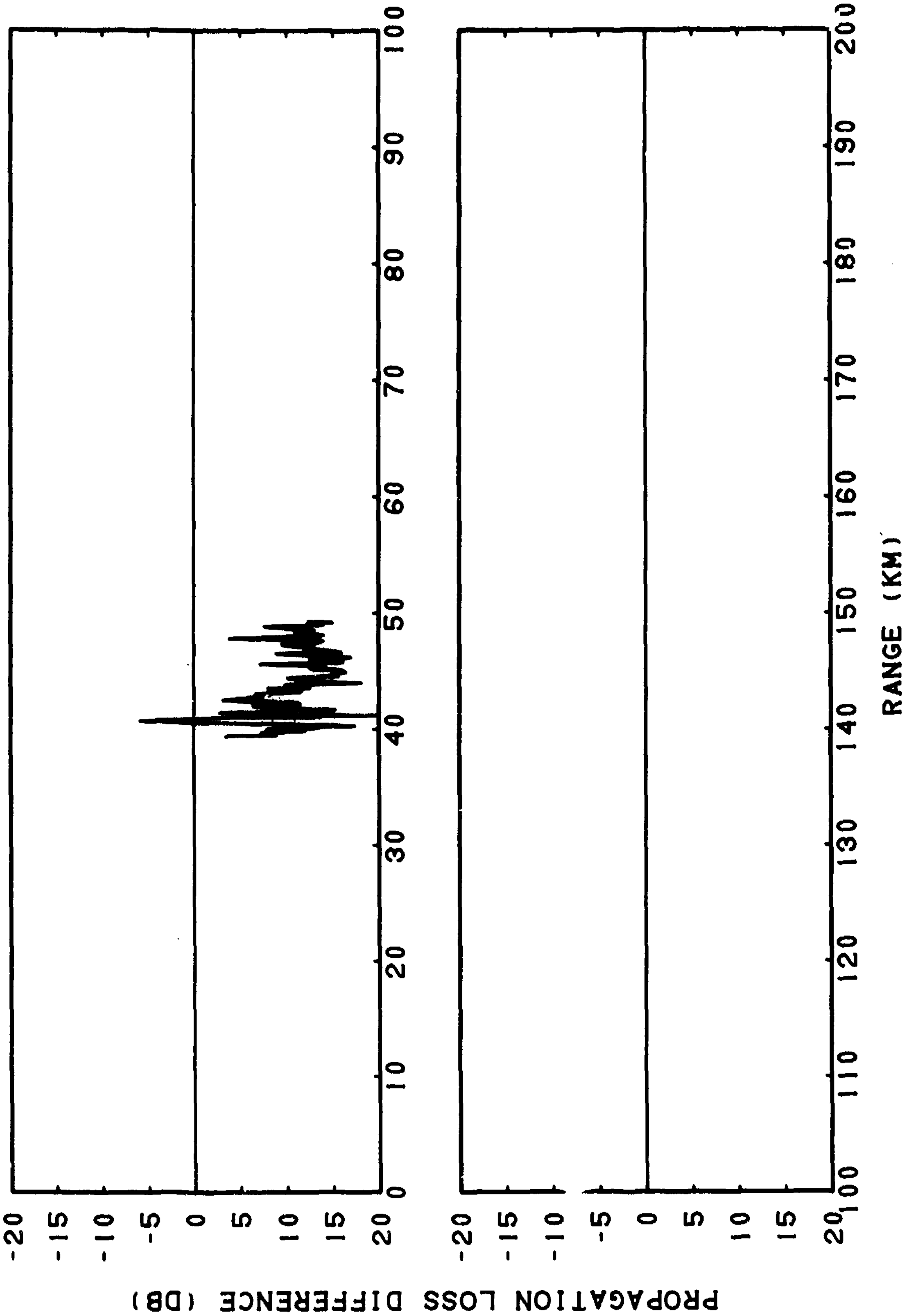
CONFIDENTIAL

(C) Figure IIIF-20b. RAYMODE Coherent Station 5 Run 43, Source Depth = 20 Feet, Receiver Depth = 260 Feet, Sliding Averages of 5 Points (0.39 Kilometer)



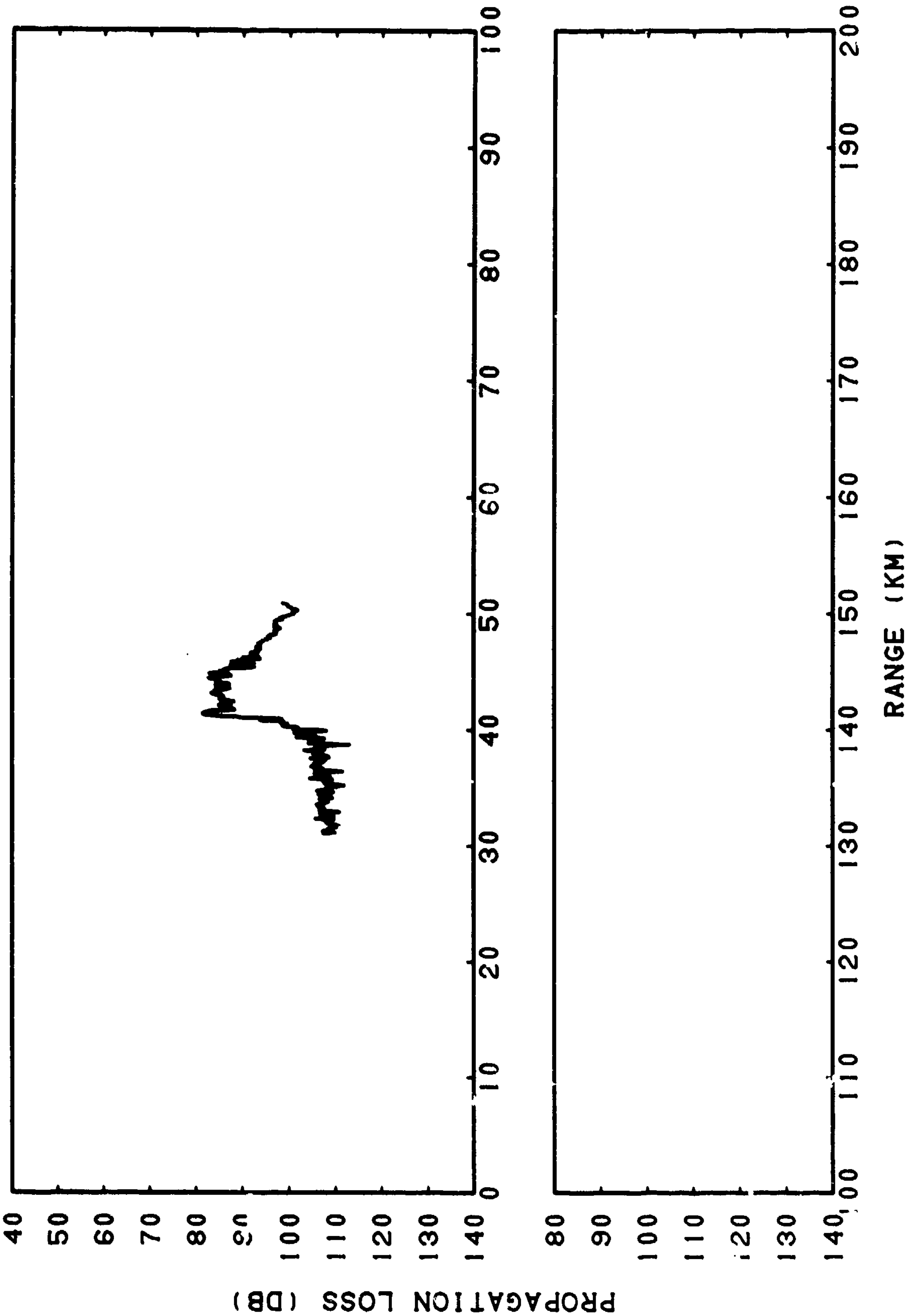
CONFIDENTIAL

(C) Figure IIIF-20c. Smoothed RAYMODE Coherent Station 5 Run 43, Source Depth = 20 Feet, Receiver Depth = 260 Feet, Subtracted from Station 5 Run 43, Source Depth = 20 Feet, Receiver Depth = 260 Feet



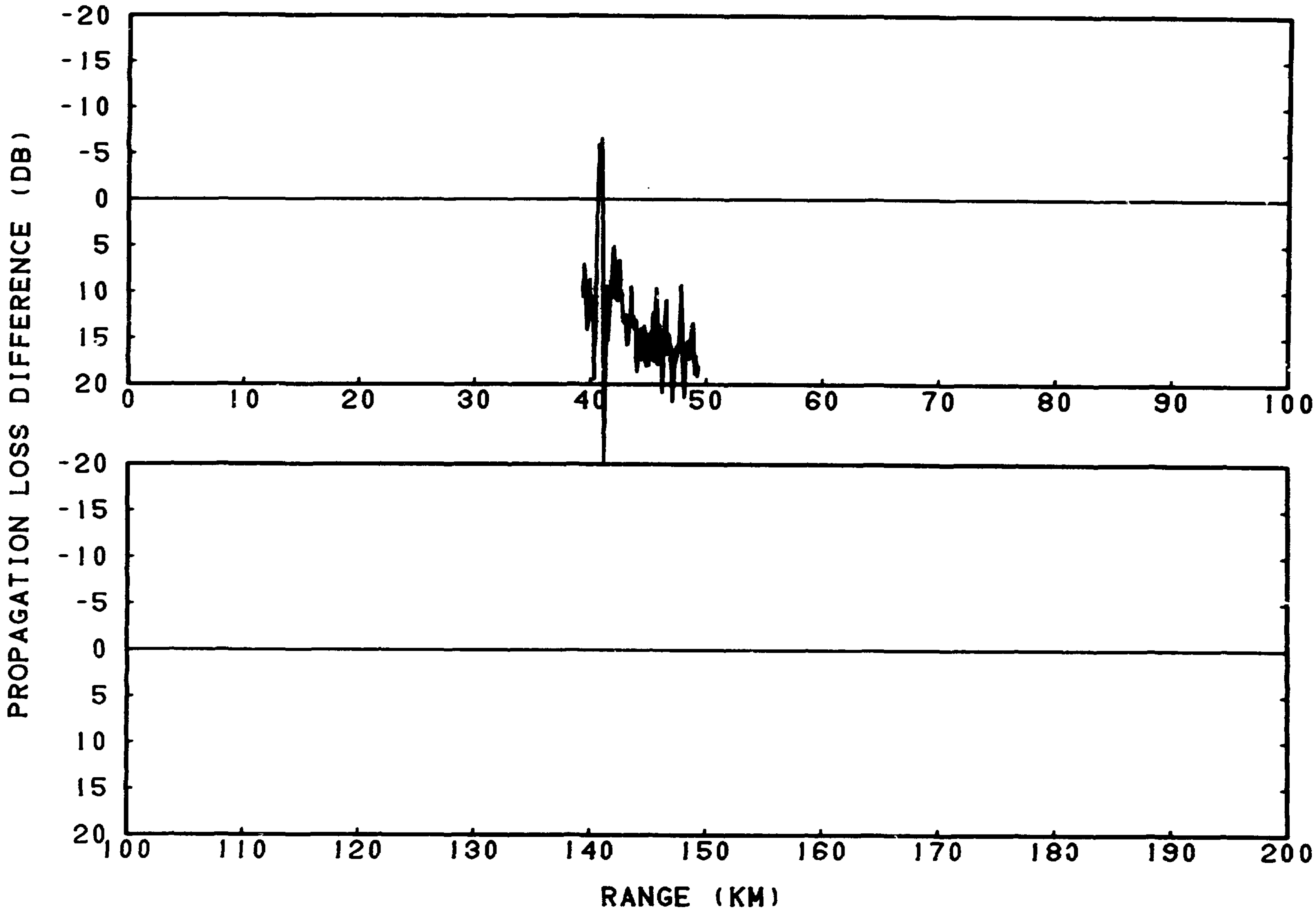
CONFIDENTIAL

(C) Figure IIIF-20d. Station 5 Run 43, Source Depth = 20 Feet, Receiver Depth = 260 Feet



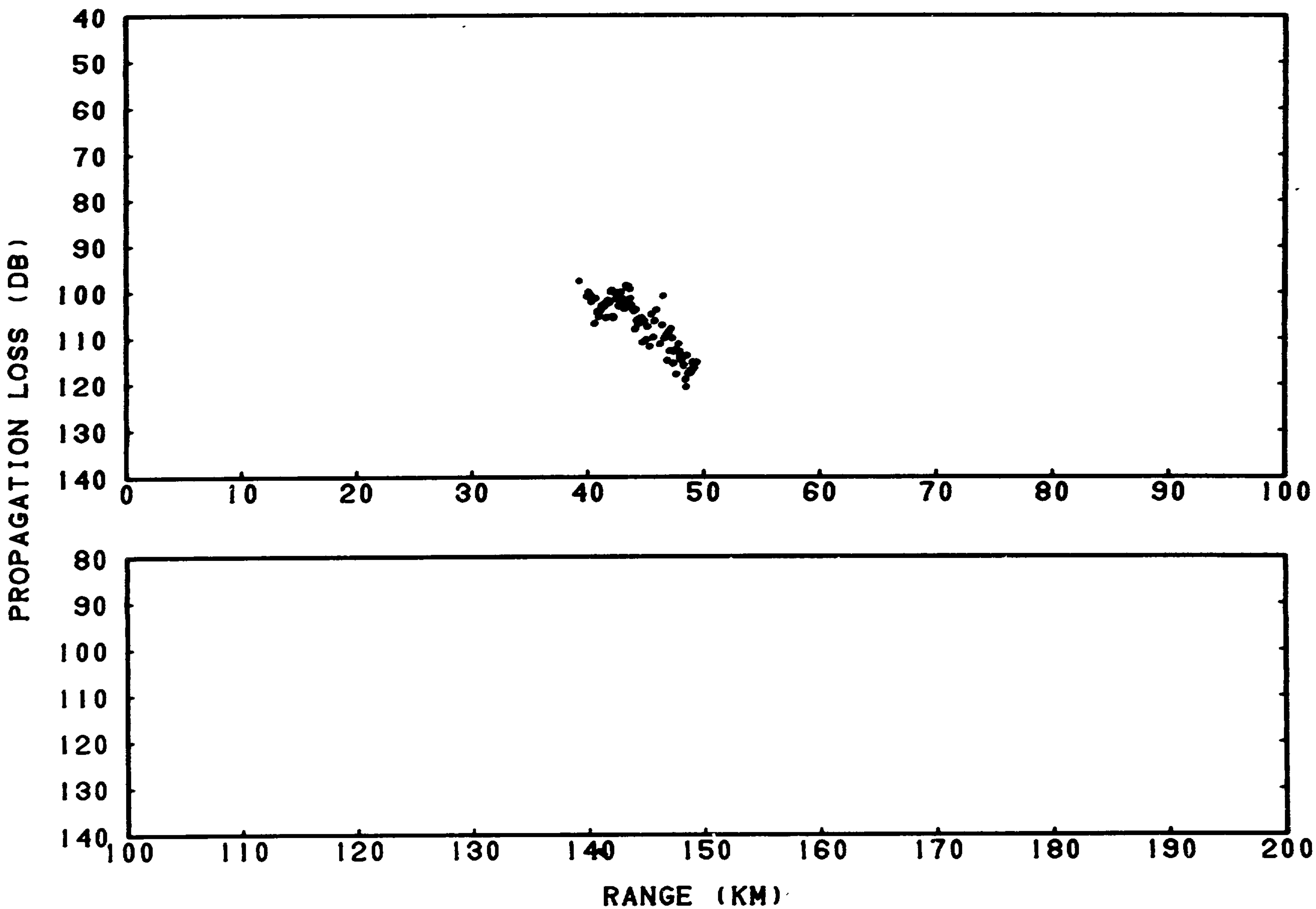
CONFIDENTIAL

(C) Figure IIIF-20e. RAYMODE Incoherent Station 5 Run 43, Source Depth = 20 Feet, Receiver Depth = 260 Feet



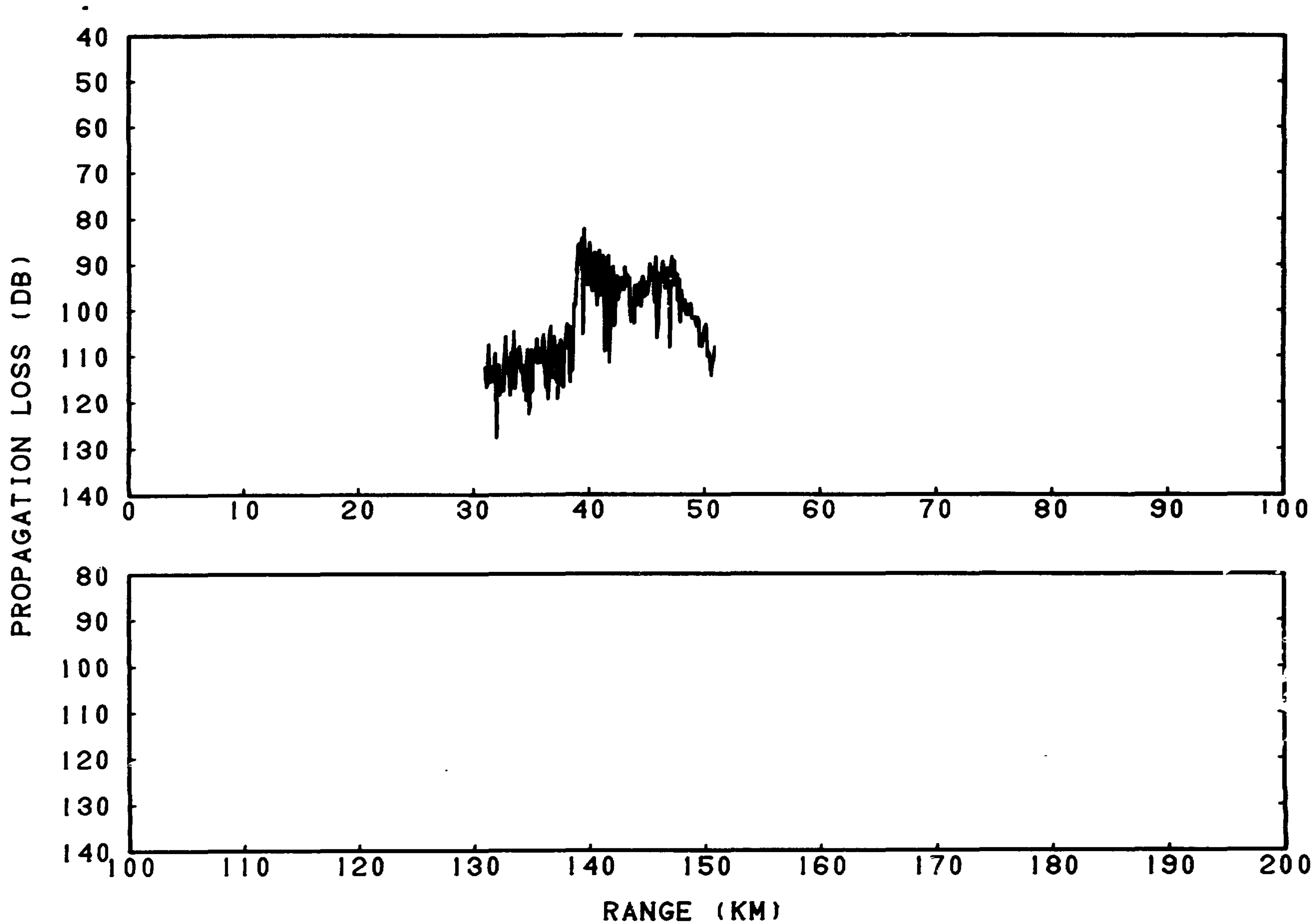
CONFIDENTIAL

(C) Figure IIIF-20f. RAYMODE Incoherent Station 5 Run 43, Source Depth = 20 Feet, Receiver Depth = 260 Feet, Subtracted from Station 5 Run 43, Source Depth = 20 Feet, Receiver Depth = 260 Feet



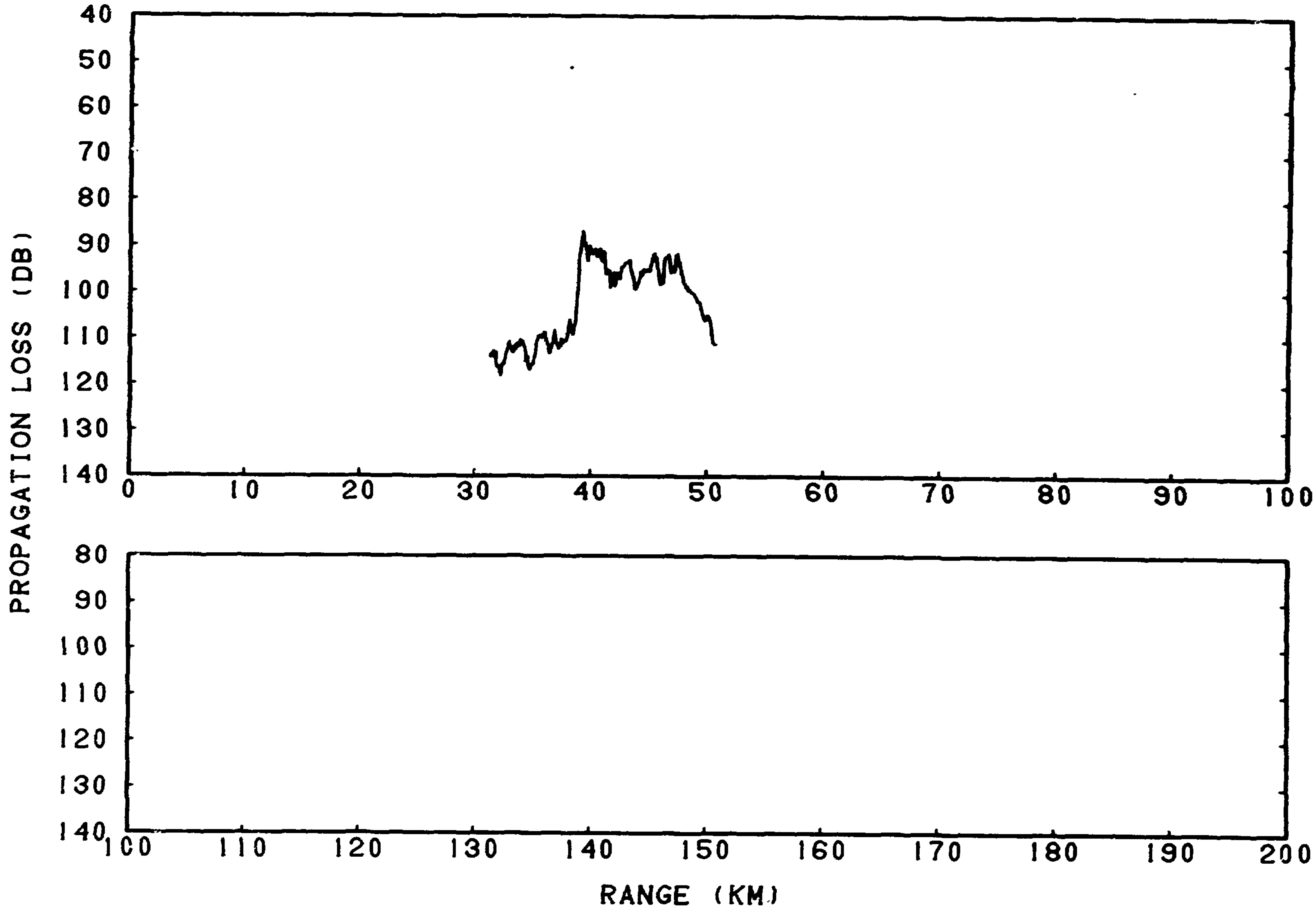
CONFIDENTIAL

(C) Figure IIIF-21a. Station 5 Run 43, Source Depth = 20 Feet, Receiver Depth = 1000 Feet



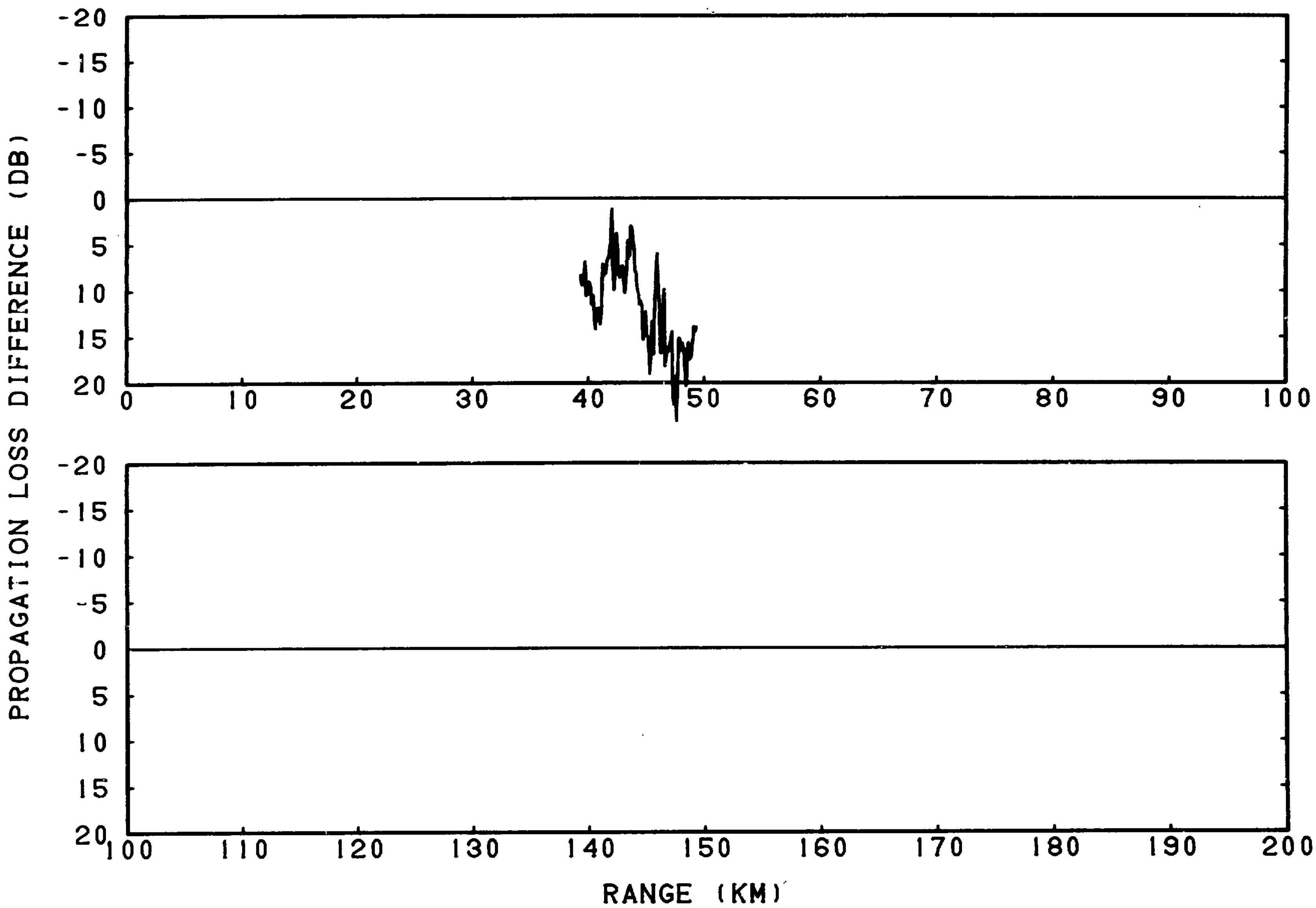
CONFIDENTIAL

(C) Figure IIIF-21b. RAYMODE Coherent Station 5 Run 43, Source Depth = 20 Feet, Receiver Depth = 1000 Feet



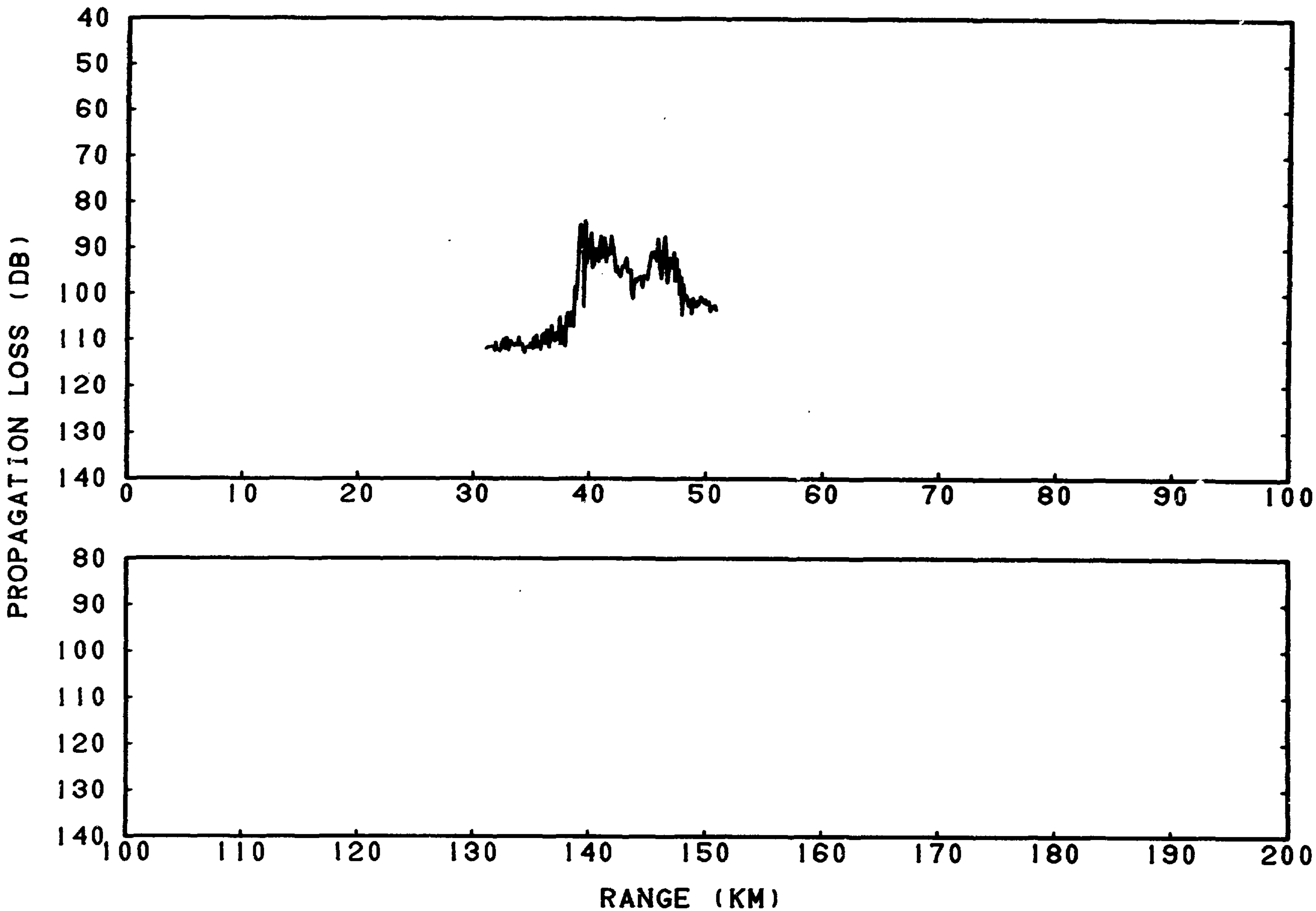
CONFIDENTIAL

(C) Figure IIIF-21c. RAYMODE Coherent Station 5 Run 43, Source Depth = 20 Feet, Receiver Depth = 1000, Sliding Averages of 5 Points (0.39 Kilometer)



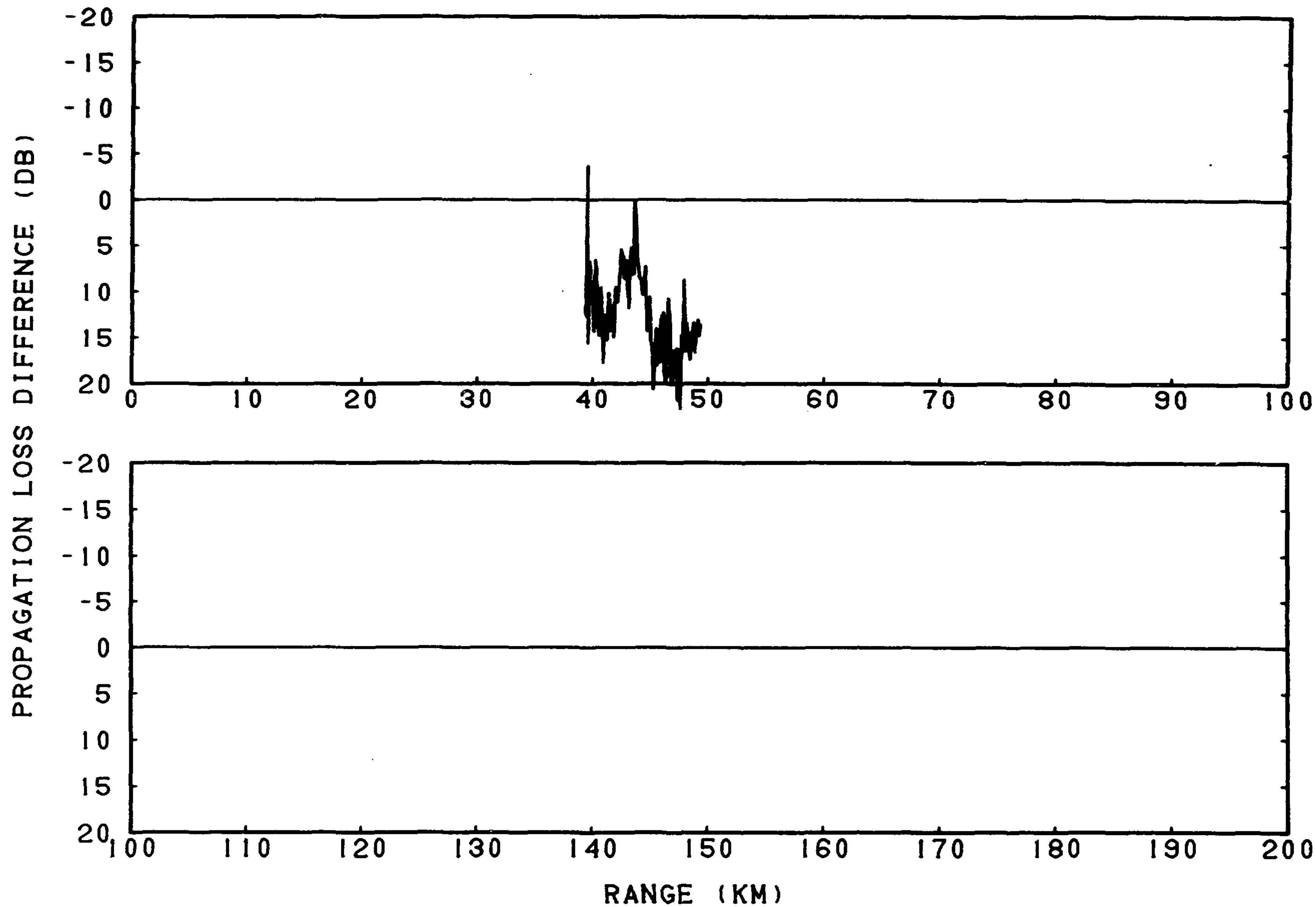
CONFIDENTIAL

(C) Figure IIIF-21d. Smoothed RAYMODE Coherent Station 5 Run 43, Source Depth = 20 Feet, Receiver Depth = 1000 Feet, Subtracted from Station 5 Run 43, Source Depth = 20 Feet, Receiver Depth = 1000 Feet



CONFIDENTIAL

(C) Figure IIIF-21e. RAYMODE Incoherent Station 5 Run 43, Source Depth = 20 Feet, Receiver Depth = 1000 Feet



CONFIDENTIAL

(C) Figure IIIF-21f. RAYMODE Incoherent Station 5 Run 43, Source Depth = 20 Feet, Receiver Depth = 1000 Feet, Subtracted from Station 5 Run 43, Source Depth = 20 Feet, Receiver Depth = 1000 Feet

Appendix IIIG. Accuracy Assessment of RAYMODE X Compared to Fasor Experimental Data (U)

FASOR (U)

Environment (U)

(C) FASOR environments deemed appropriate for the evaluation of range independent propagation loss models were from stations designated as FIG, OAK, THORN, and REDWOOD (Martin, 1982). The sound speed versus depth profiles and their tabulations are given for these stations in Figures IIIG1-IIIG4, respectively. The station FIG sound speed profile consists of three negative gradients, representative of an arctic environment. The first gradient extends to 75 m, the second gradient is a strong thermocline to 150 m, and the third gradient is the pressure-induced gradient which extends to the bottom at 7648 m. The station OAK sound speed profile consists of a surface duct to 30 m overlying a sound channel with substantial negative depth excess which intersects the bottom at 120 m. The station THORN sound speed profile consists of a negative gradient (i.e., a surface duct) to 55 m over a strong positive gradient intersecting the bottom at 104 m. The sound speed structure at station REDWOOD is a broad sound channel with axis at 1200 m. The channel is bottom limited and intersects the bottom at 3282 m. The negative depth excess is approximately 1600 m.

(C) The bottom loss versus grazing angle curves selected are not those normally associated with the RAYMODE X model, but rather the same curves used in Appendix IIG of Volume II of this series (i.e., the FNOC curves found in the FACT PL9D propagation loss model). Since bottom interaction effects are significant in this environment, use of RAYMODE X's internal MGS bottom loss classes and curves might lead to better agreement with data. The use of the same bottom loss curves in FACT PL9D and RAYMODE X does permit direct comparison of these models for the FASOR environments. The bottom loss versus grazing angle curve for station FIG is plotted in Figure IIIG-5 and listed in Table IIIG-1. The loss at 0° is 8 dB; at 18° the loss has risen to 15 dB. From 19° to 90°, the bottom loss is between 15 and 16 dB. For stations OAK and THORN the bottom loss is plotted in Figure IIIG-6 and listed in Table IIIG-2. The loss rises from a value of 3.5 dB at 0° to a normal incidence value of 9 dB; at 15° the bottom loss is 4.5 dB. The bottom loss versus grazing angle for station REDWOOD is plotted in Figure IIIG-7 and listed in Table IIIG-3. The loss at 0° is 13 dB; at 10° the loss is 24 dB. The bottom loss versus grazing angle curve has two maxima: 28.2 dB at 25° and 26.5 dB at 80°.

Test Cases (U)

(U) Six test cases from the FASOR experiments were selected for model evaluation and are shown on the following page.

(C) Cases IIa and IIb pertain to a single environment and Cases IIIa and IIIb pertain to a different but single environment. Between Cases IIa and IIb there is a data gap between 24.5 and 26 km. Cases IIIa and IIIb have a data overlap between 19.5 and 25.5 km. As mentioned above, Case II (i.e., station OAK) has a surface duct; the acoustic source is in the duct and the receiver is below the duct. This case will therefore be dominated by contributions from bottom interacting paths. Case III (i.e., station THORN) also has a surface duct; in this case both source and receiver are in the duct and trapped energy should dominate acoustic transmission. Station FIG (Case I) is characterized by negative gradients and

CASE	STATION	RUN NUMBER (m)	SOURCE DEPTH	RECEIVER DEPTH (m)	FREQUENCY (kHz)	MINIMUM RANGE (km)	MAXIMUM RANGE (km)
I	FIG	3	6.1	37	1.5	6.0	54.0
IIa	OAK	1	23.0	37	1.5	26.0	44.0
IIb	OAK	2	23.0	37	1.5	12.0	24.5
IIIa	THORN	1	23.0	37	1.5	19.5	33.5
IIIb	THORN	2	23.0	37	1.5	12.0	25.5
IV	REDWOOD	3	6.1	37	1.5	1.0	36.0

hence almost all energy will be transmitted from the shallow source to the shallow receiver (both in the uppermost gradient) by surface-reflected paths with negligible bottom-reflected energy. The station REDWOOD sound speed profile would indicate significant bottom interaction; however, however, a high loss (FNOC Type 8) bottom diminishes this contribution.

Accuracy Assessment Results (U)

(U) The accuracy assessment procedures were followed as outlined in section 1.1 of this volume and described in detail in section 5 of Volume I of this series. The following figures are given for each case: (1) The FASOR experimental data for the six cases in Figures IIIG-8-13. (2) The FASOR data smoothed by application of a running average with a 2 km window and overlap of 25%, resulting in a point every 0.5 km. The smoothed data are plotted in Figures IIIG-14-19. (3a) RAYMODE X coherent output; (3b) RAYMODE X coherent output subtracted from the smoothed FASOR data; (3c) RAYMODE X incoherent output; (3d) RAYMODE X incoherent output subtracted from smoothed FASOR data. These plots (i.e., (3a)-(3d)) are given for each case in Figures IIIG-20-43.

(C) The means and standard deviations of differences between the smoothed FASOR data and the RAYMODE X results are given in Table IIIG-4. For Case I, the agreement between the smoothed FASOR data and RAYMODE X is remarkable beyond 35 km for the incoherent phase option. Overall, the FASOR data and RAYMODE predictions are quit- consistent. Discrepancies are basically due to fine scale str· cure; For Case IIa, the FASOR data show less loss than the RAYMODE X prediction over almost the entire range extent. Over most of the range interval, the incoherent result is in closer agreement to the FASOR data than is the coherent result by approximately 6 dB. In Case IIb the FASOR data rides about 3 dB above (i.e., at lower loss) the low loss peaks of the RAYMODE X coherent prediction. The variability is reduced and hence overall agreement is enhanced for the RAYMODE X incoherent prediction. In Case IIIa the smoothed FASOR data shows more structure than the RAYMODE X coherent prediction (unsmoothed). The FASOR data shows greater propagation loss than the RAYMODE predictions in this case. In Case IIIb the RAYMODE X predictions show the same basic trends as the FASOR data, leading to basically low values of mean and standard deviation for the two RAYMODE coherence options. For Case IV, despite some large fluctuations, RAYMODE X predictions capture the basically complex shape of the FASOR data. The RAYMODE curves show a severe increase in propagation loss at about 30 km. This same increase is seen in the FASOR data at about 28 km and is followed by a recovery at about 32 km which quickly falls off again to high loss values of propagation loss.

(C) The results of the Figure of Merit (FOM) analysis are found in Tables IIIG-5 to IIIG-10 for the six cases. For Case I, the RAYMODE predictions are optimistic for FOM = 85 dB. At FOM = 90 dB, RAYMODE coherent predicts longer ranges than FASOR data and RAYMODE incoherent predicts shorter detection ranges. For FOM = 90 dB, both FASOR data and RAYMODE predictions yield approximately the same detection coverage. For Case IIa, FASOR data gives greater detection coverage than RAYMODE X predictions at all figures of merit (≤105 dB) regardless of model phase option. For Case IIb, FASOR gives greater detection coverage by about 20% than RAYMODE at FOM = 90 dB. For FOM ≥ 95 dB, FASOR and RAYMODE detection coverage is basically the same. For Case IIIa, detection coverage is basically the same for FASOR and RAYMODE X at FOM = 80 and 85 dB; at FOM = 90 dB, FASOR gives a maximum detection range of 28 km whereas RAYMODE predicts greater than 33 km. With the exception of RAYMODE X incoherent at FOM = 75 dB, FASOR data and RAYMODE predictions are in basic agreement regarding detection coverage over figures of merit between 75 and 85 dB. For Case IV, short detection ranges (<6 km) are found for RAYMODE and FASOR for FOM ≤ 90 dB. At FOM = 95 or 100 dB, detection coverage given by FASOR is much greater than that predicted by RAYMODE X. For FOM ≥ 105 dB, FASOR and RAYMODE results are in basic agreement.

(C) Aside from Case IIa, agreement between FASOR data and RAYMODE X predictions is qualitatively good. For Case IIa, the model is utilizing a low loss bottom and a significant reduction of levels is probably unachievable with available bottom loss curves. Overall, there is a slight tendency for the FASOR results to show less loss and give slightly better detection coverage, although this varies from case to case and also depends upon the RAYMODE coherence option chosen.

References (U)

Martin, R. L., et al. (1982). Summary of Range Independent Environment Acoustic Propagation Data Sets (U). Vol. IA, The Acoustic Model Evaluation Committee (AMEC) Reports, NORDA Report 34, Naval Ocean Research and Development Activity, NSTL Station, Miss. (CONFIDENTIAL)

(C) Table IIIG-1. Bottom Loss in dB versus Grazing Angle in degrees for FASOR. Station FIG (FNOC Type 5). Frequency = 1500 Hertz.

Θ	BL	Θ	BL	Θ	BL	Θ	BL	Θ	BL	Θ	BL
0	8.05	15	14.42	30	15.84	45	15.37	60	14.89	75	15.11
1	8.70	16	14.63	31	15.84	46	15.33	61	14.88	76	15.15
2	9.32	17	14.82	32	15.84	47	15.28	62	14.88	77	15.19
3	9.90	18	14.99	33	15.82	48	15.24	63	14.88	78	15.22
4	10.45	19	15.14	34	15.80	49	15.20	64	14.88	79	15.26
5	10.96	20	15.27	35	15.78	50	15.15	65	14.89	80	15.30
6	11.43	21	15.39	36	15.75	51	15.12	66	14.90	81	15.34
7	11.88	22	15.49	37	15.72	52	15.08	67	14.91	82	15.37
8	12.29	23	15.57	38	15.68	53	15.05	68	14.93	83	15.41
9	12.68	24	15.65	39	15.64	54	15.01	69	14.94	84	15.44
10	13.03	25	15.71	40	15.60	55	14.99	70	14.97	85	15.48
11	13.36	26	15.75	41	15.56	56	14.96	71	14.99	86	15.50
12	13.66	27	15.79	42	15.51	57	14.94	72	15.02	87	15.53
13	13.44	28	15.82	43	15.47	58	14.92	73	15.05	88	15.55
14	14.19	28	15.84	44	15.42	59	14.90	74	15.08	89	15.57

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(C) Table IIIG-2. Bottom Loss in dB versus Grazing Angle in degrees for FASOR Stations OAK and THORN (FNOC Type 2, Frequency = 1500 Hertz).

Θ	BL	Θ	BL	Θ	BL	Θ	BL	Θ	BL	Θ	BL
0	3.49	15	4.77	30	6.48	45	7.91	60	8.72	75	8.95
1	3.54	16	4.88	31	6.59	46	7.98	61	8.75	76	8.96
2	3.60	17	5.00	32	6.70	47	8.06	62	8.78	77	8.96
3	3.67	18	5.11	33	6.81	48	8.13	63	8.81	78	8.96
4	3.74	19	5.22	34	6.91	49	8.19	64	8.83	79	8.96
5	3.81	20	5.34	35	7.01	50	8.26	65	8.85	80	8.96
6	3.89	21	5.45	36	7.11	51	8.32	66	8.87	81	8.96
7	8.98	22	5.57	37	7.21	52	8.37	67	8.89	82	8.96
8	4.07	23	5.69	38	7.31	53	8.43	68	8.90	83	8.96
9	4.16	24	5.80	39	7.40	54	8.48	69	8.91	84	8.96
10	4.25	25	5.90	40	7.49	55	8.53	70	8.92	85	8.96
11	4.35	26	6.03	41	7.58	56	8.57	71	8.93	86	8.97
12	4.45	27	6.15	42	7.67	57	8.61	72	8.94	87	8.97
13	4.56	28	6.26	43	7.75	58	8.65	73	8.95	88	8.98
14	4.67	29	6.37	44	7.83	59	8.69	74	8.95	89	8.99

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(C) Table IIIG-3. Bottom Loss in dB versus Grazing Angle in degrees for FASOR Station REDWOOD (FNOC Type 8, Frequency = 1500 Hertz).

Θ	BL	Θ	BL	Θ	BL	Θ	BL	Θ	BL	Θ	BL
0	13.07	15	26.67	30	27.80	45	25.69	60	25.08	75	26.26
1	14.61	16	27.01	31	27.69	46	25.58	61	25.13	76	26.32
2	16.05	17	27.30	32	27.56	47	25.47	62	25.18	77	26.38
3	17.38	18	27.54	33	27.43	48	25.38	63	25.25	78	26.42
4	18.61	19	27.73	34	27.28	49	25.29	64	25.32	79	26.44
5.	18.74	20	27.89	35	27.13	50	25.22	65	25.39	80	26.45
6	20.78	21	28.00	36	26.98	51	25.15	66	25.48	81	26.44
7	21.73	22	28.09	37	26.83	52	25.10	67	25.56	82	26.40
8	22.60	23	28.14	38	26.68	53	25.06	68	25.65	83	26.34
9	23.39	24	28.16	39	26.52	54	25.03	69	25.74	84	26.26
10	24.11	25	28.15	40	26.37	55	25.01	70	25.84	85	26.14
11	24.75	26	28.12	41	26.22	56	25.00	71	25.93	86	25.99
12	25.32	27	28.07	42	26.08	57	25.01	72	26.02	87	25.81
13	25.83	28	28.00	43	25.94	58	25.02	73	26.10	88	25.59
14	26.28	29	27.91	44	25.81	59	25.05	74	26.18	89	25.32

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(C) Table IIIG-4. Means (μ) and Standard Deviations (σ) of Differences Obtained by Subtracting RAYMODE X Coherent and Incoherent Outputs from Smoothed[1] FASOR Experimental Data (in dB).

Case	Station	Run	Coherent Phase		Incoherent Phase	
			μ	σ	μ	σ
I	FIG	3	0.7	6.2	2.1	3.4
IIa	OAK	1	-8.9	4.7	-2.3	2.2
IIb	OAK	2	-8.2	4.8	-3.2	0.7
IIIa	THORN	1	6.9	1.9	4.0	1.8
IIIb	THORN	2	1.5	2.0	-1.4	2.0
IV	REDWOOD	3	-6.1	6.9	-3.1	4.2

1. Smoothed by running average with a 2 kilometer window and 25% overlap thereby generating one point every 0.5 km.

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(C) Table IIIG-5. Detection Range in km as a Function of Figure of Merit (FOM) in dB for FASOR[1] Data (6-54 km) and RAYMODE X Model[2] Results. (Station FIG, Run 3, Source Depth = 6.1 m, Receiver Depth = 37 m, Frequency = 1.5 kHz.

Data Set	FOM	R_c[3]	Range > R_c
FASOR	85	?	ZDC[4] 50%, 6-8.5 km
RAYMODE X Coherent	85	7.0	ZDC 80%, 7.0-12.0 km; ZDC 75%, 15-20 km Coverage 25.5-26 km
RAYMODE X Incoherent	85	10.5	ZDC 50%, 11-18.5 km
FASOR	90	17.0	ZDC 75%, 25-29 km ONE PEAK at 32 km
RAYMODE X Coherent	90	7.5	ZDC 70%, 7.5-33.5 km. Peaks at 45.5 km, 47.5 km, 50 km
RAYMODE X Incoherent	90	10.5	ZDC 50%, 11-18.5 km
FASOR	95	18.0	ZDC 70%, 18-52 km
RAYMODE X Coherent	95	12.0	ZDC 80%, 12.0-38 km ZDC 35%, 42.5-54 km
RAYMODE X Incoherent	95	43.0	
FASOR	100	>54.0	
RAYMODE X Coherent	100	22.0	ZDC 80%, 22.5-54 km
RAYMODE X Incoherent	100	>54.0	
FASOR	105	>54.0	
RAYMODE X Coherent	105	34.5	ZDC 80%, 34.5-54 km
RAYMODE X Incoherent	105	>54.0	
FASOR	110	>54.0	
RAYMODE X Coherent	110	39.0	100% coverage 54 km except for loss 39-40 km
RAYMODE X Incoherent	110	>54.0	

1. FASOR data were not smoothed.
2. RAYMODE X Model Results were not Smoothed.
3. Range to which coverage is continuous.
4. ZDC = Zonal Detection Coverage in percentage of indicated range interval over which detection is possible.

(C) Table IIIG-6. Detection Range in km as a Function of Figure of Merit (FOM) in dB for FASOR[1] Data (26-44 km) and RAYMODE X Model[2] Results. (Station OAK, Run 1, Source Depth = 23 m, Receiver Depth = 37 m, Frequency = 1.5 kHz.

Data Set	FOM	R_c[3]	Range > R_c
FASOR	105	29	50% coverage 36-44 km; ZDC[4] 70%, 29-32 km; 100% coverage 32-36 km
RAYMODE X Coherent	105	<26	100% coverage 26-27 km and 29.5-31 km
RAYMODE X Incoherent	105	27.5	
FASOR	110	39	ZDC 60%, 39-44 km
RAYMODE X Coherent	110	<26	100% coverage 26-27.5 km, 29-31 km and 32-33 km
RAYMODE X Incoherent	110	38	
FASOR	115	>44	
RAYMODE X Coherent	115	<26	ZDC 50% 37-41 km; 100% coverage 26-27.5 km, 28.5-31 km, and 31.5-35 km
RAYMODE X Incoherent	115	44	

1. FASOR data were not smoothed.
2. RAYMODE X Model Results were not Smoothed.
3. R_c = Range to which converage is continuous.
4. ZDC = Zonal Detection Coverage in percentage of indicated range interval over which detection is possible.

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(C) Table IIIG-7. Detection Range in km as a Function of Figure of Merit (FOM) in dB for FASOR[1] data (12-24.5 km) and RAYMODE X Model[2] Results. (Station OAK, Run 2, Source Depth = 23 m, Receiver Depth = 37 m, Frequency = 1.5 kHz.

Data Set	FOM	R_c [3]	Range > R_c
FASOR	90	18.0	ZDC[4] 50%, 18-22 km
RAYMODE X Coherent	90	11.0	ZDC 50%, 11.0-17.0 km
RAYMODE X Incoherent	90	18.0	
FASOR	95	23.0	
RAYMODE X Coherent	95	12.0	ZDC 70% 12.0-19 km; Peak at 23 km
RAYMODE X Incoherent	95	23.0	
FASOR	100	>24.5	
RAYMODE X Coherent	100	15.0	ZDC 65% 15.0 to >24.5 km
RAYMODE X Incoherent	100	>24.5	
FASOR	105	>24.5	
RAYMODE X Coherent	105	19.5	100% coverage 20-24 km
RAYMODE X Incoherent	105	>24.5	

1. FASOR data were not smoothed.
2. RAYMODE X Model Results were not Smoothed.
3. R_c = Range to which coverage is continuous.
4. ZDC = Zonal Detection Coverage in percentage of indicated range interval over which detection is possible.

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(C) Table IIIG-8. Detection Range in km as a Function of Figure of Merit (FOM) in dB for FASOR[1] Data (19.5-33.5 km) and RAYMODE X Model[2] Results. (Station THORN, Run 1, Source Depth = 23 m, Receiver Depth = 37 m, Frequency = 1.5 kHz).

Data Set	FOM	R_c [3]	Range > R_c
FASOR	80	<19.5	ZDC[4] 10%, 19.5-27 km
RAYMODE X Coherent	80	29.0	
RAYMODE X Incoherent	80	22.0	
FASOR	85	<19.5	ZDC 65%, 19.5-23.5 km, ZDC 20%, 23.5-33.5 km
RAYMODE X Coherent	85	<33.5	
RAYMODE X Incoherent	85	<33.5	
FASOR	90	28.0	
RAYMODE X Coherent	90	<33.5	
RAYMODE X Incoherent	90	<33.5	

1. FASOR data were not smoothed.
2. RAYMODE X Model Results were not Smoothed.
3. R_c = Range to which coverage is continuous.
4. ZDC = Zonal Detection Coverage in percentage of indicated range interval over which detection is possible.

(C) Table IIIG-9. Detection Range in km as a Function of Figure of Merit (FOM) in dB for FASOR[1] Data (12-25.5 km) and RAYMODE X Model[2] Results. (Station THORN, Run 2, Source Depth = 23 m, Receiver Depth = 37 m, Frequency = 1.5 kHz.

Data Set	FOM	R_c[3]	Range $> R_c$
FASOR	75	<12.0	ZDC[4] 60%, 12-21 km
RAYMODE X Coherent	75	17.0	Coverage 17.5-18 km
RAYMODE X Incoherent	75	11.5	
FASOR	80	14.5	ZDC 80%, 14.5-24 km
RAYMODE X Coherent	80	>25.5	
RAYMODE X Incoherent	80	22.0	
FASOR	85	22.0	ZDC 60%, 22-25.5 km
RAYMODE X Coherent	85	>25.5	
RAYMODE X Incoherent	85	>25.5	

1. FASOR data were not smoothed.
2. RAYMODE X Model Results were not smoothed.
3. R_c = Range to which coverage is continuous.
4. ZDC = Zonal Detection Coverage in percentage of indicated range interval over which detection is possible.

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(C) Table IIIG-10. Detection Range in km as a Function of Figure of Merit (FOM) in dB for FASOR[1] Data (1-36 km) and RAYMODE X Model[2] Results. (Station REDWOOD, Run 3, Source Depth = 6.1m, Receiver Depth = 37 m, Frequency = 1.5 kHz).

Data Set	FOM	R_c[3]	Range > R_c
FASOR	85	?	
RAYMODE X Coherent	85	2.0	Peak at 2.5 km
RAYMODE X Incoherent	85	3.0	
FASOR	90	2.5	
RAYMODE X Coherent	90	3.0	Peak at 4.0 km
RAYMODE X Incoherent	90	4.0	
FASOR	95	5.0	ZDC[4] 60%, 5-11 km
RAYMODE X Coherent	95	5.0	
RAYMODE X Incoherent	95	6.0	
FASOR	100	11.5	ZDC 50%, 11.5-24.5 km
RAYMODE X Coherent	100	6.0	Peaks at 7.0 km, 7.5 km, 8.5 km, 13.5 km, 27 km
RAYMODE X Incoherent	100	7.5	100% coverage 7.5-8.5 km, and 9.0 km
FASOR	105	28.5	One dropout from 15 to 16 km
RAYMODE X Coherent	105	6.0	ZDC 45%, 6.5-28.5 km
RAYMODE X Incoherent	105	13.0	100% coverage 13.5-14 km, 14.5-15 km, 24-28.5 km and 29 km
FASOR	110	28.5	
RAYMODE X Coherent	110	10.0	ZDC 70%, 10.5-29 km
RAYMODE X Incoherent	110	30.0	
FASOR	115	29.0	One peak between 32 and 33 km
RAYMODE X Coherent	115	11.0	ZDC 85%, 11.0-30.5 km
RAYMODE X Incoherent	115	30.5	

1. FASOR Data were not smoothed.
2. RAYMODE X Model Results were not Smoothed.
3. R_c = Range to which coverage is continuous.
4. ZDC = Zonal Detection Coverage in percentage of indicated range interval over which detection is possible.

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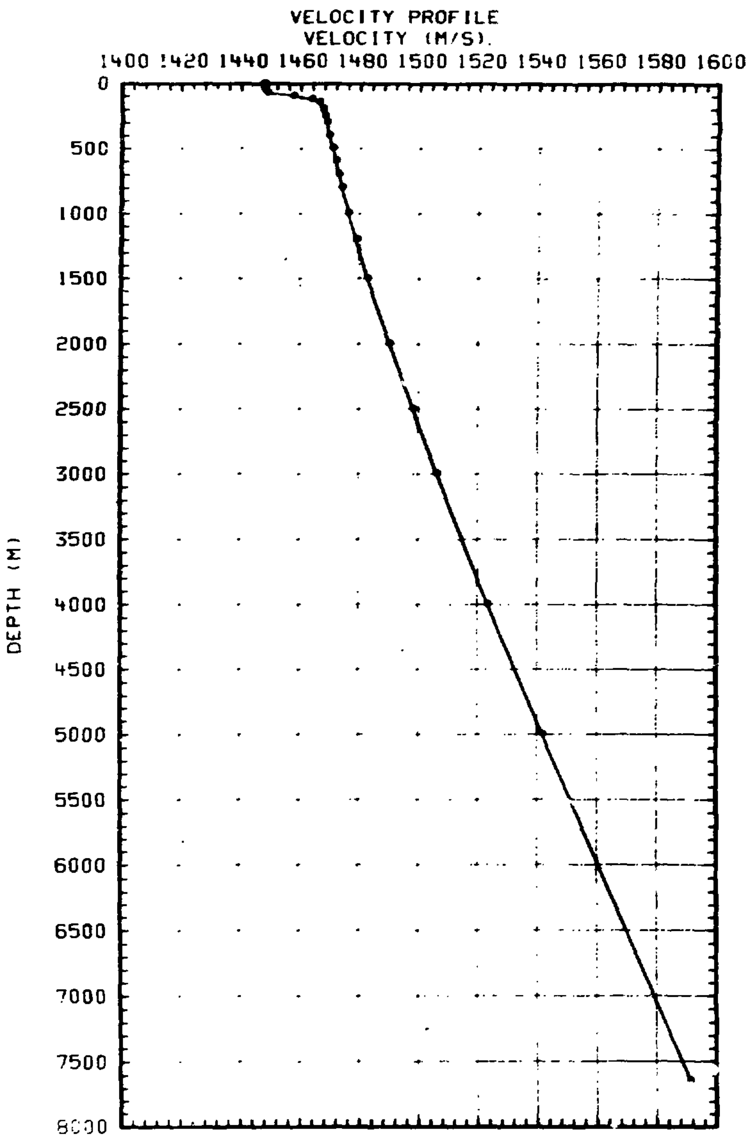
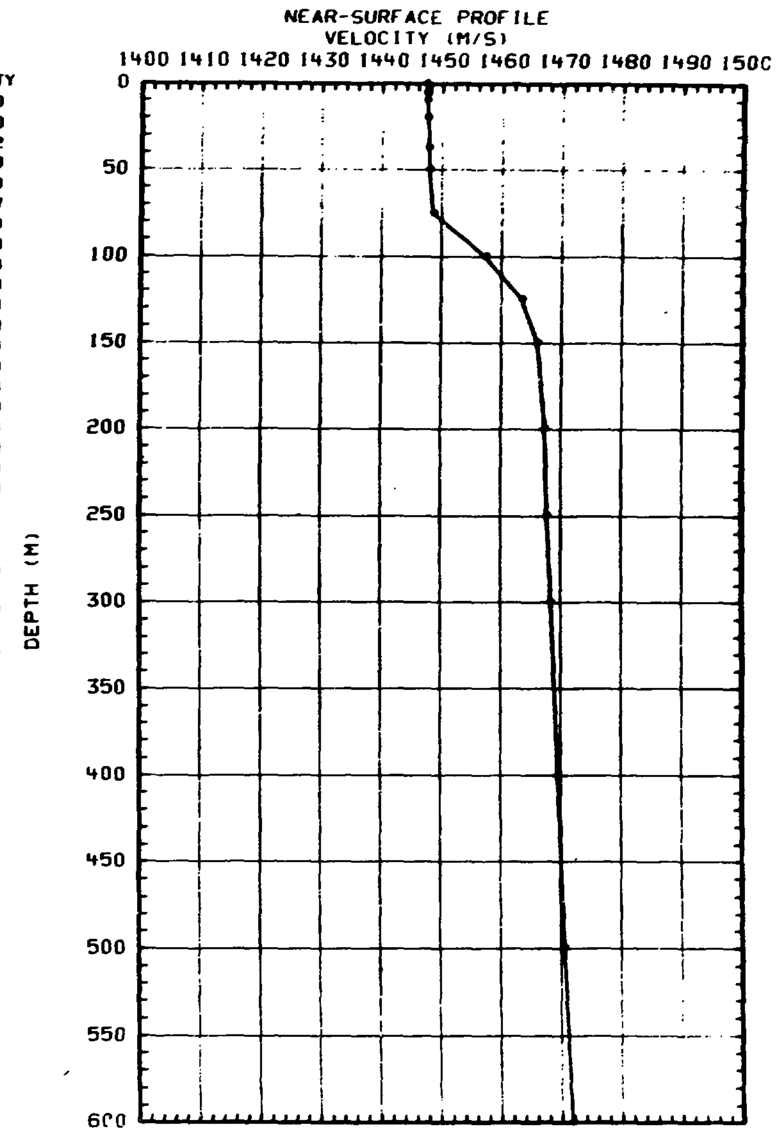


DEPTH	VELOCITY
0.0	1447.30
5.0	1447.40
6.1	1447.42
10.0	1447.50
20.0	1447.60
37.0	1447.77
50.0	1447.90
75.0	1448.60
100.0	1457.30
125.0	1463.40
150.0	1466.00
200.0	1467.30
250.0	1467.70
300.0	1468.40
400.0	1469.50
500.0	1470.60
600.0	1471.70
700.0	1472.80
800.0	1473.90
1000.0	1476.20
1200.0	1478.60
1500.0	1482.60
2000.0	1490.20
2500.0	1498.10
3000.0	1506.30
4000.0	1523.50
5000.0	1541.80
7648.0	1591.30



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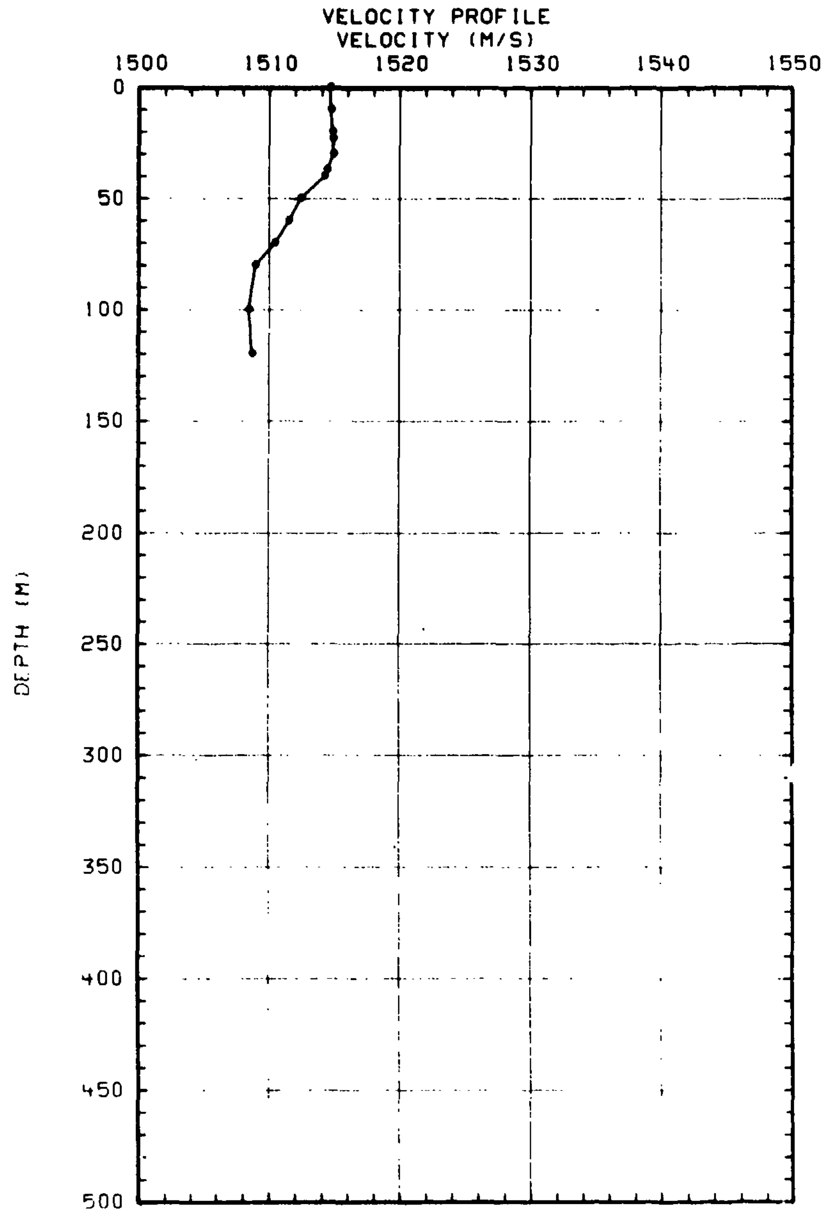
(U) Figure IIIG-1. Sound Speed Versus Depth Profile for FASOR Station FIG



DEPTH	VELOCITY
0.0	1514.60
10.0	1514.70
20.0	1514.80
23.0	1514.83
30.0	1514.90
37.0	1514.41
40.0	1514.20
50.0	1512.40
60.0	1511.50
70.0	1510.40
80.0	1508.90
100.0	1508.40
120.0	1508.70

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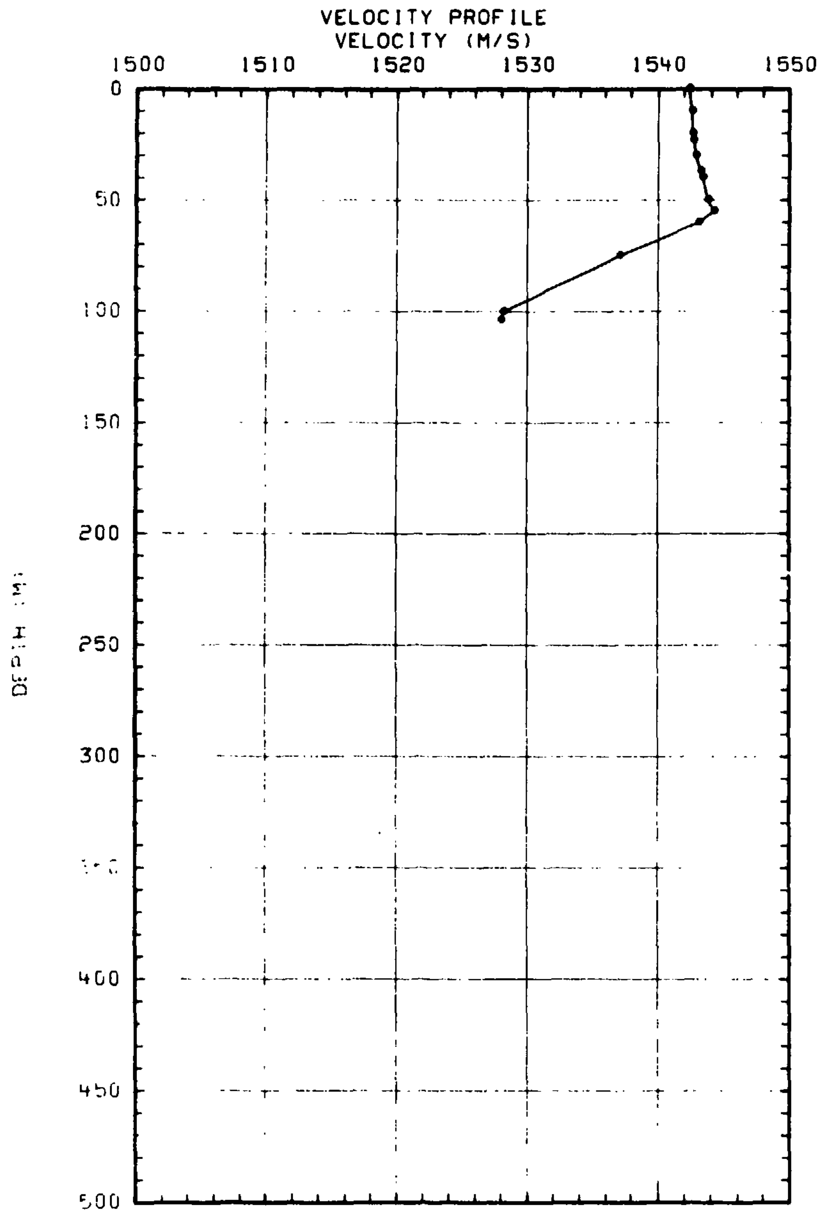
(U) Figure IIIG-2. Sound Speed Versus Depth Profile for FASOR Station OAK



DEPTH	VELOCITY
0.0	1542.40
10.0	1542.60
20.0	1542.70
23.0	1542.76
30.0	1542.90
37.0	1543.25
40.0	1543.40
50.0	1543.80
55.0	1544.20
60.0	1543.10
75.0	1537.20
100.0	1528.20
104.0	1528.00

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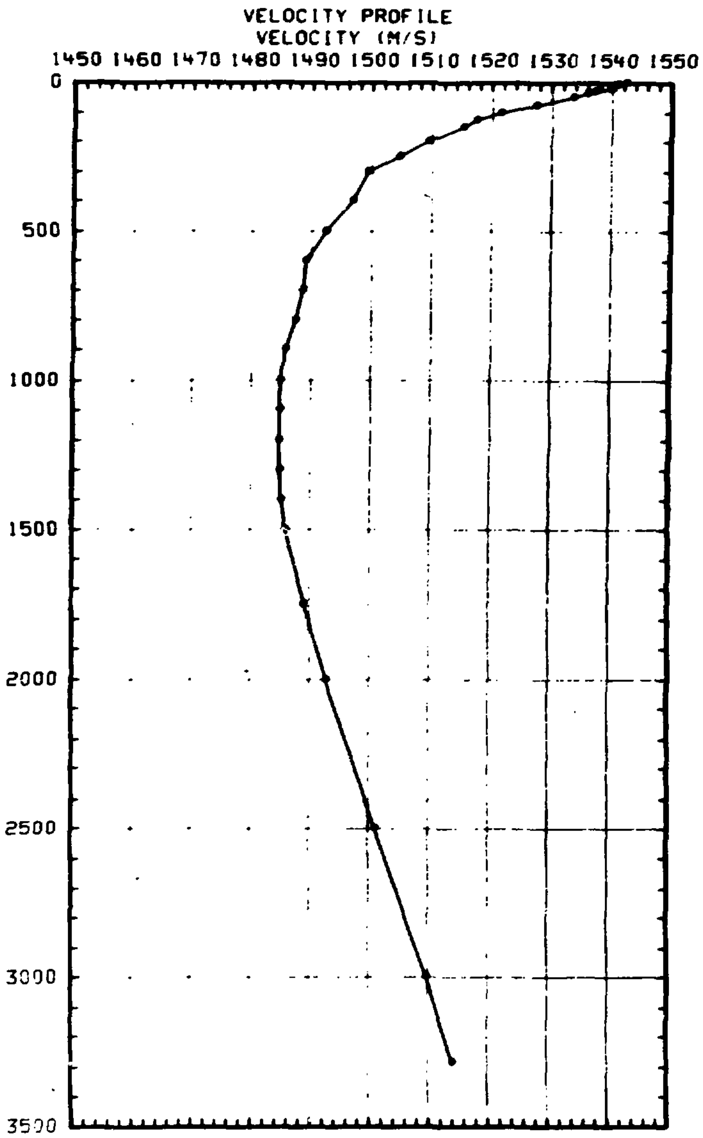
(U) Figure IIIG-3. Sound Speed Versus Depth Profile for FASOR Station THORN



DEPTH	VELOCITY
0.0	1542.30
6.1	1540.90
10.0	1540.00
19.0	1540.10
20.0	1538.70
30.0	1537.10
37.0	1535.87
50.0	1533.60
75.0	1527.30
100.0	1521.40
125.0	1517.30
150.0	1515.10
200.0	1509.40
250.0	1504.60
300.0	1498.30
400.0	1496.80
500.0	1492.30
600.0	1488.00
700.0	1488.50
800.0	1487.30
900.0	1485.60
1000.0	1484.90
1100.0	1484.70
1200.0	1484.60
1300.0	1484.80
1400.0	1485.10
1500.0	1485.80
1750.0	1489.10
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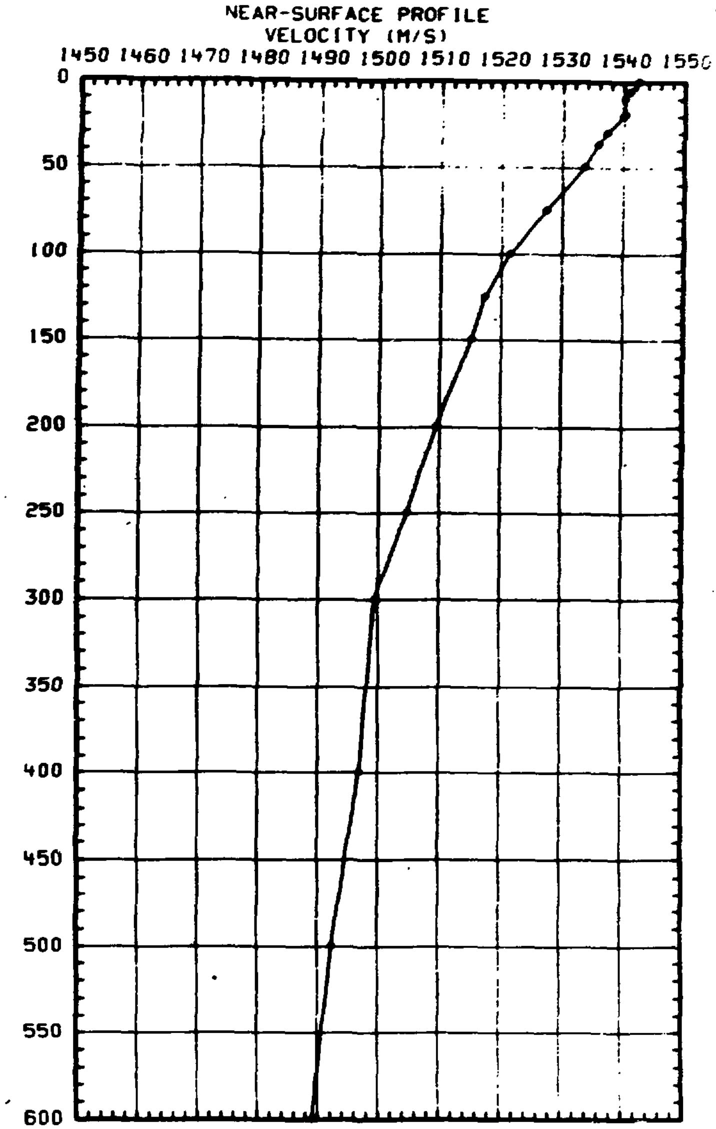
2500.0	1501.10
3000.0	1509.70
3282.0	1514.00



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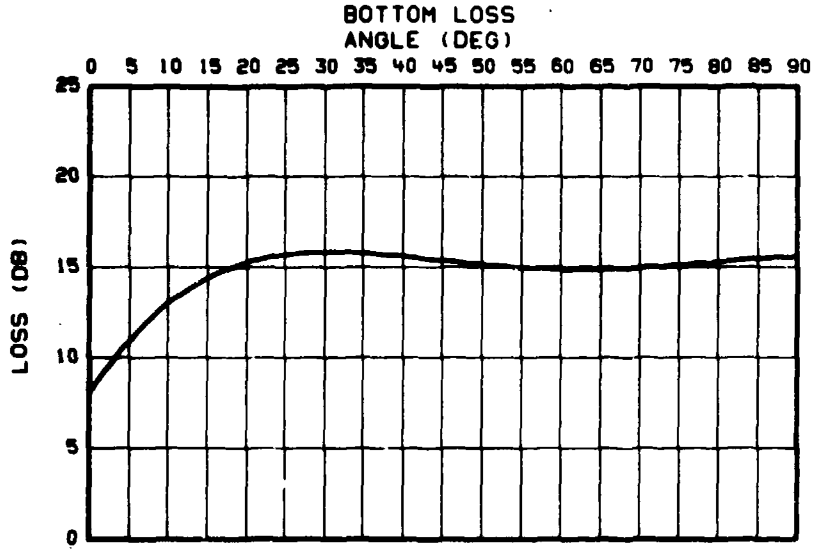
(U) Figure IIIG-4. Sound Speed Versus Depth Profile for FASOR Station REDWOOD



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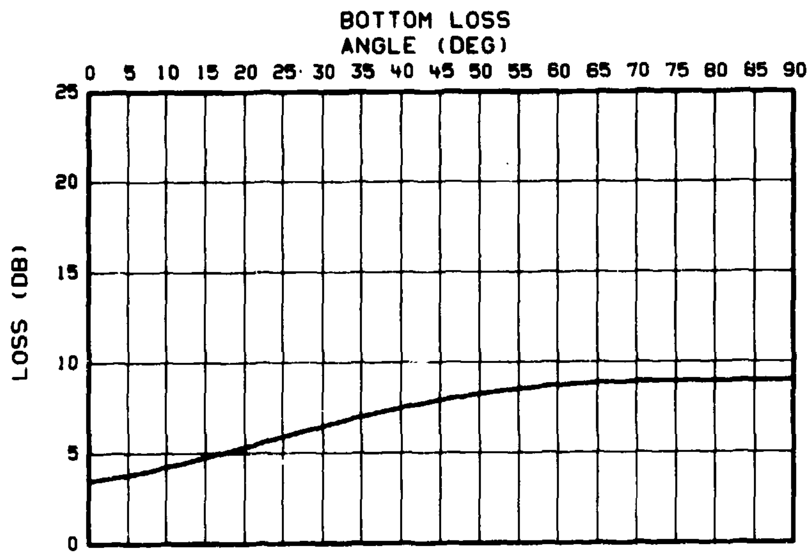
(C) Figure IIIG-5. Bottom Loss Versus Grazing Angle for FASOR Station FIG (FNOC Type 5, Frequency = 1.5 Kilohertz)



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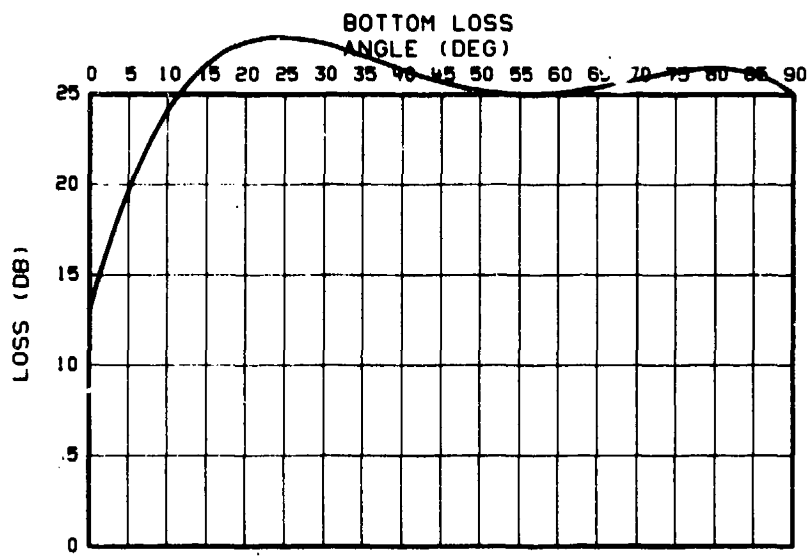
(C) Figure IIIG-6. Bottom Loss Versus Grazing Angle for FASOR Stations OAK and THORN (FNOC Type 2, Frequency = 1.5 Kilohertz)



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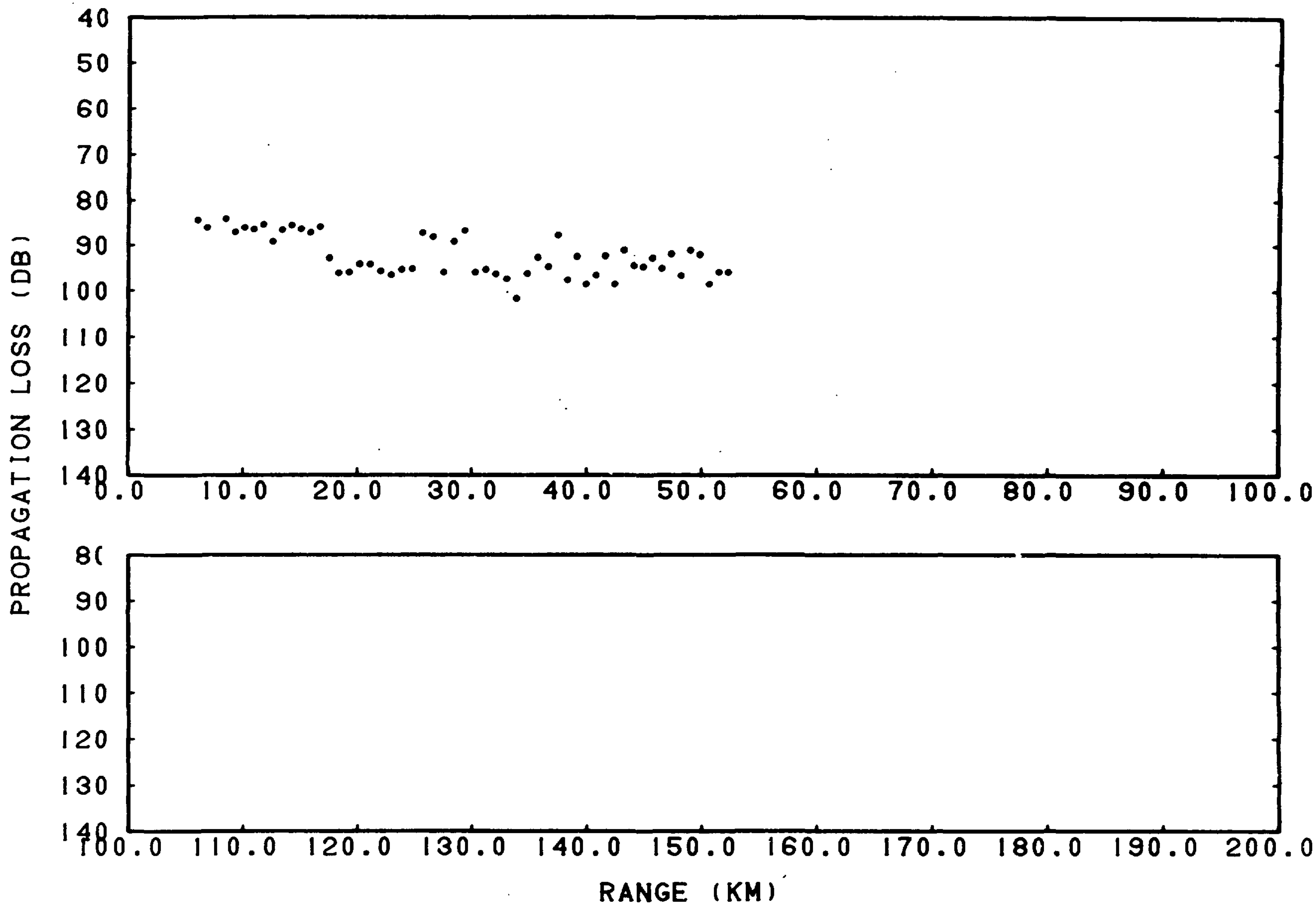
(C) Figure IIIG-7. Bottom Loss Versus Grazing Angle for FASOR Station REDWOOD (FNOC Type 8, Frequency = 1.5 Kilohertz)



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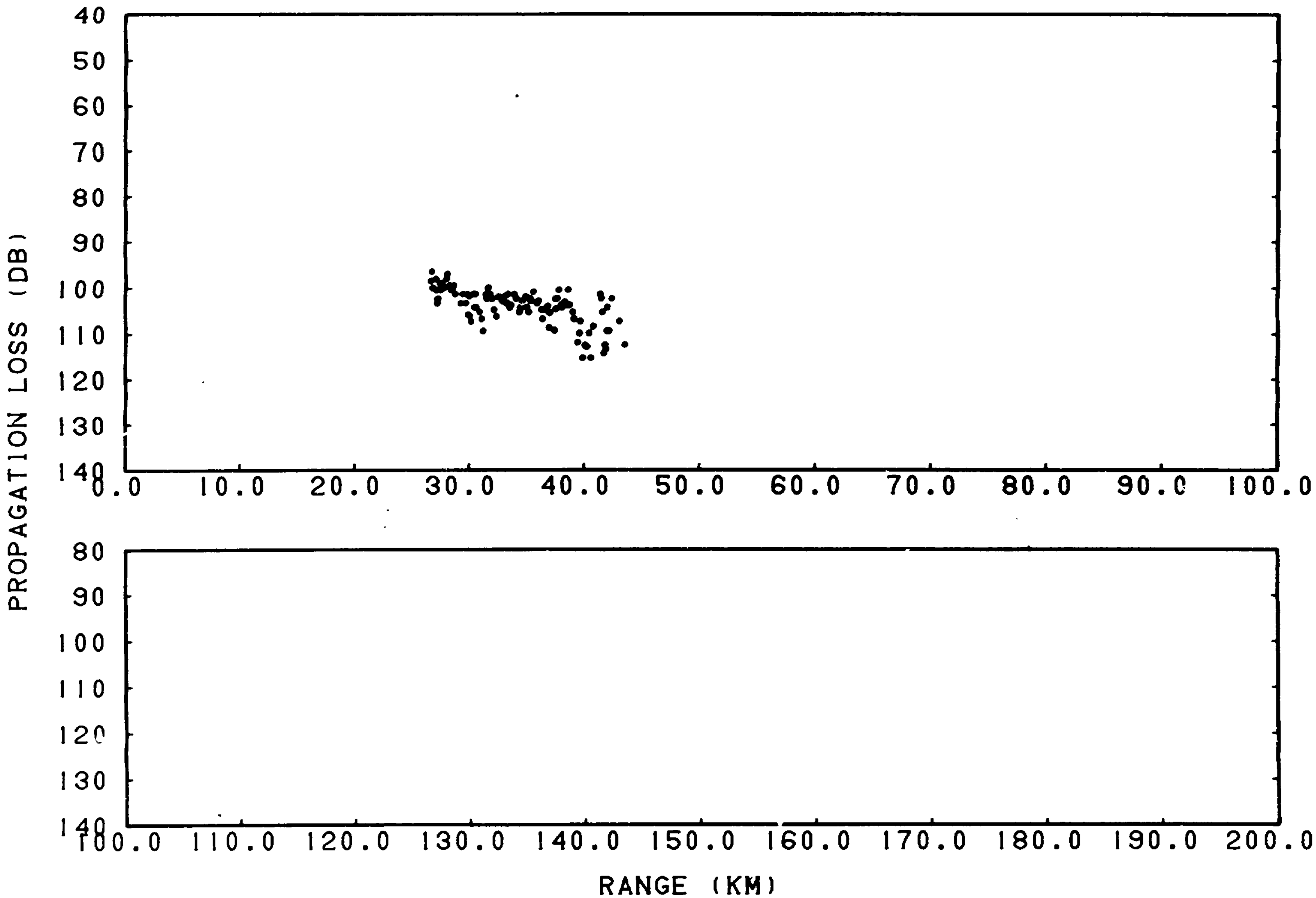
(C) Figure IIIG-8. FASOR Station FIG, Run 3, Source Depth = 6.1 Meters, Receiver Depth = 37 Meters, Frequency = 1500 Hertz



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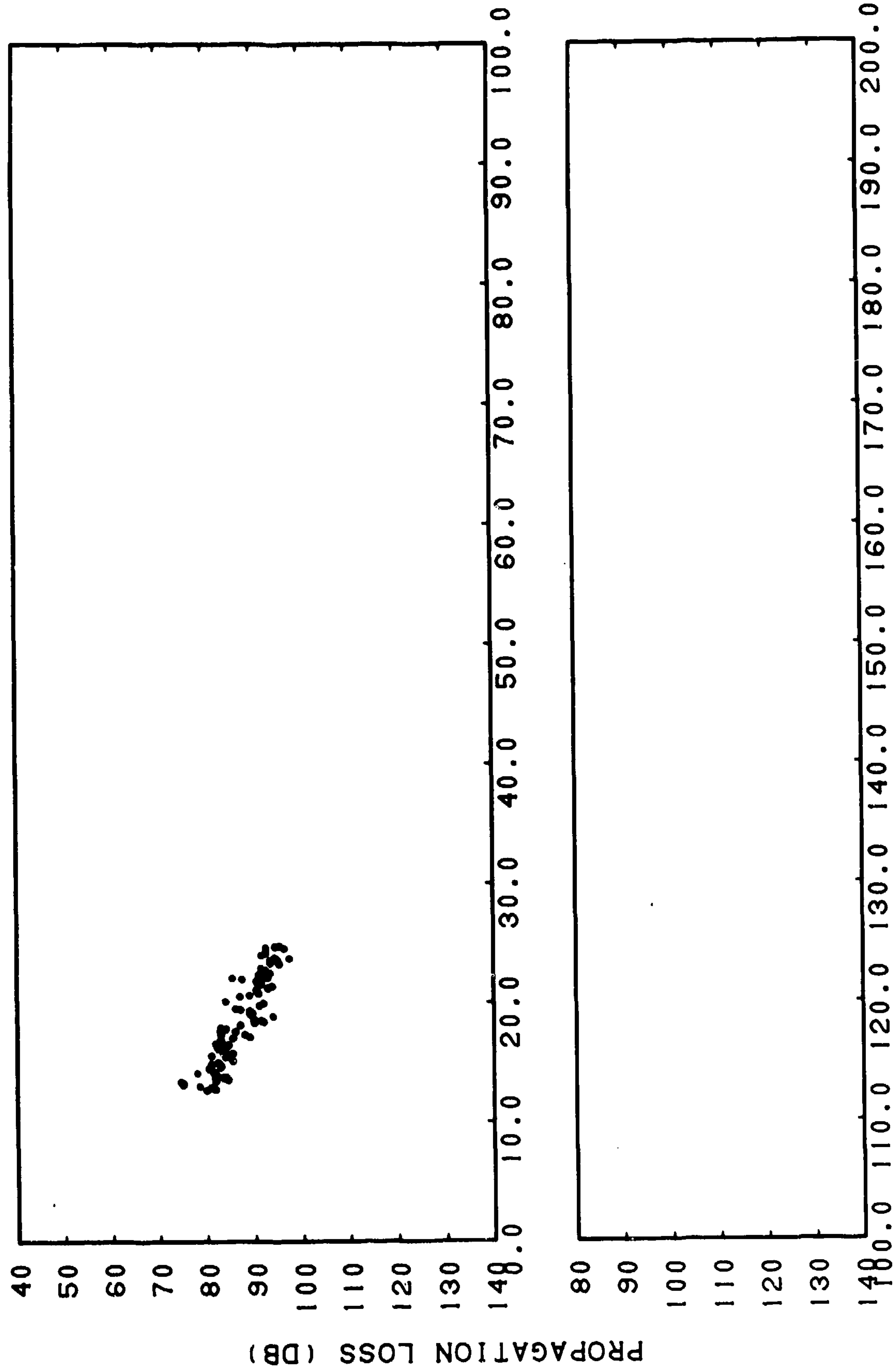
(C) Figure IIIG-9. FASOR Station OAK, Run 1, Source Depth = 23 Meters, Receiver Depth = 37 Meters, Frequency = 1500 Hertz



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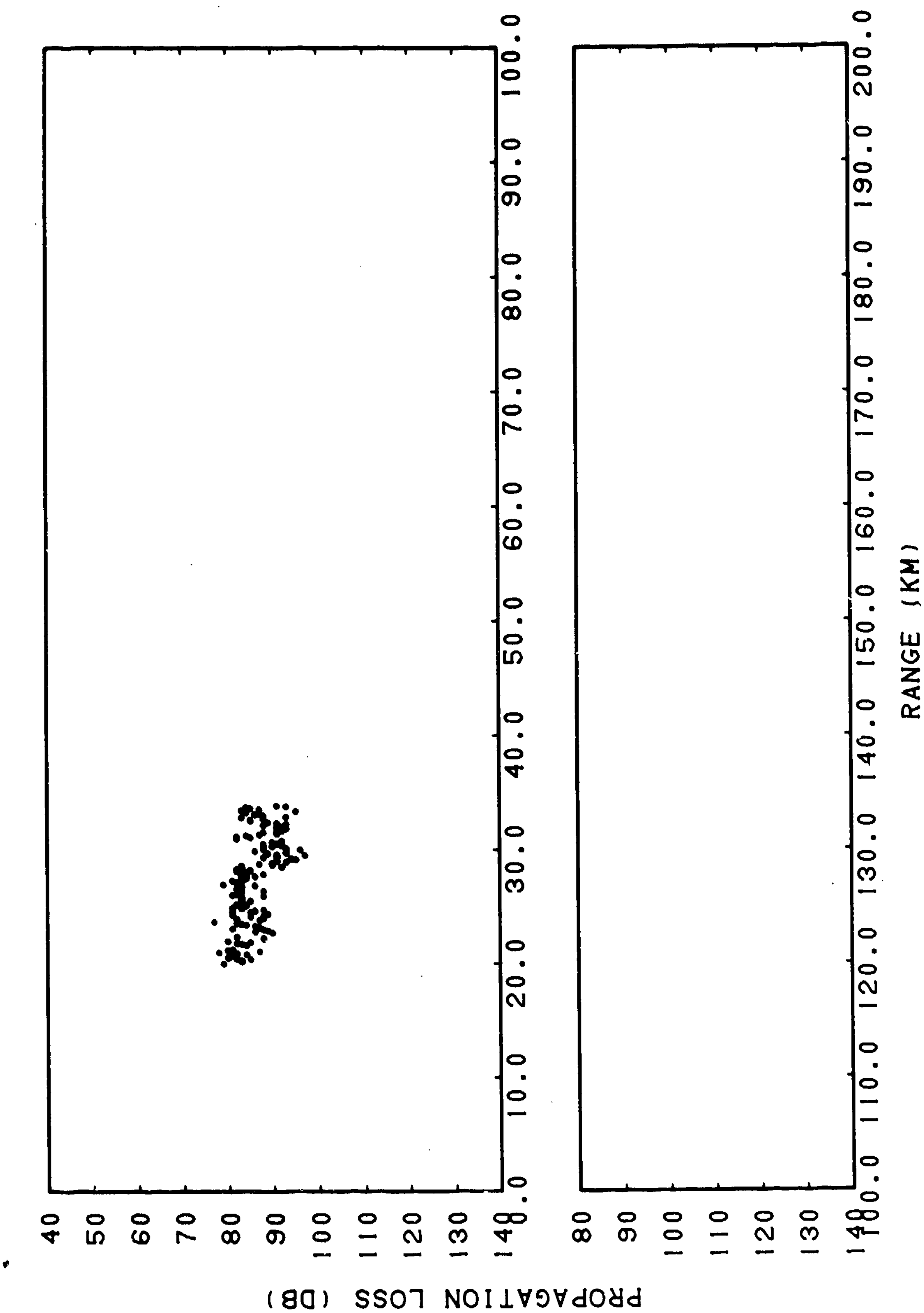
(C) Figure IIIG-10. FASOR Station OAK, Run 2, Source Depth = 23 Meters, Receiver Depth = 37 Meters, Frequency = 1500 Hertz



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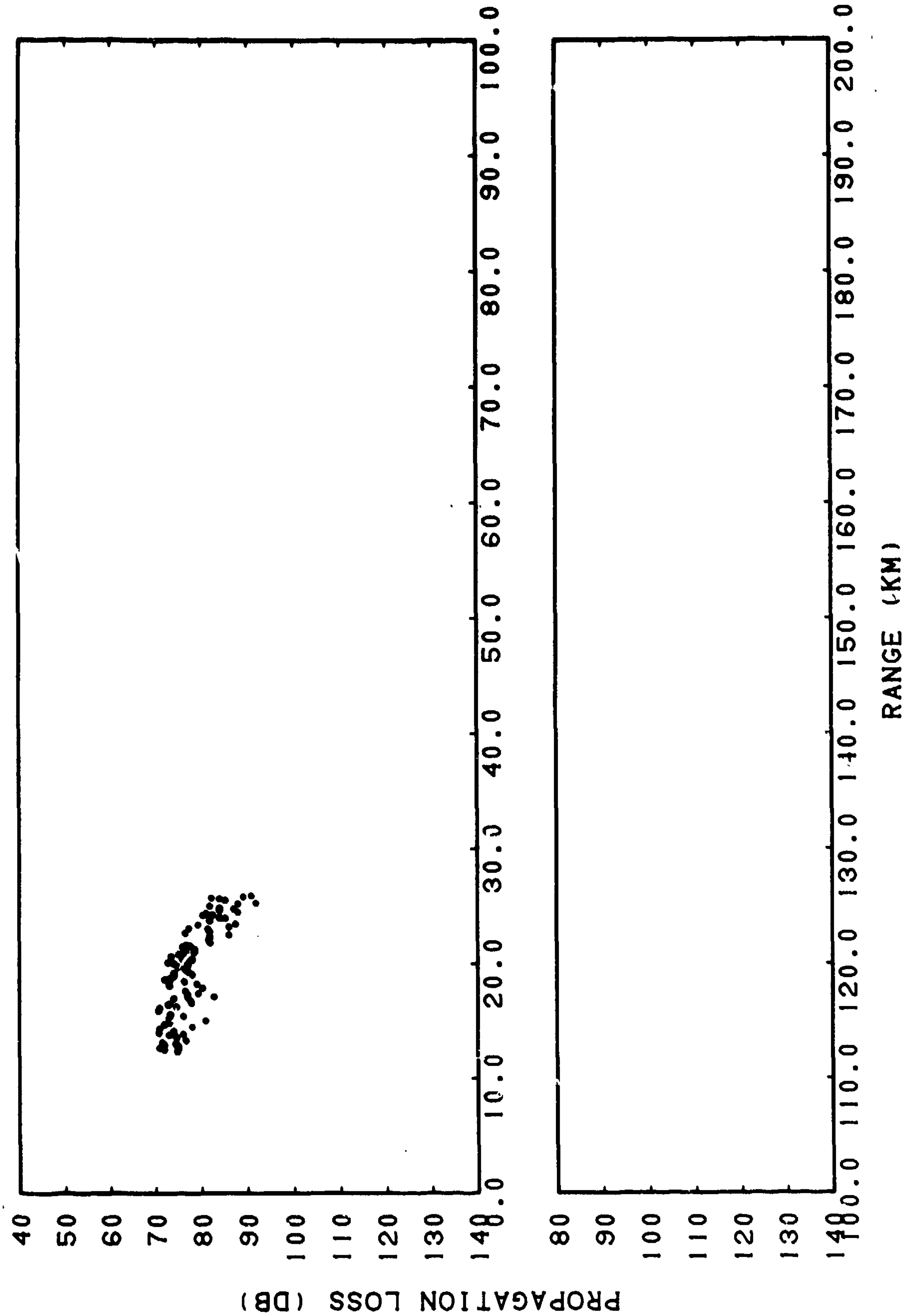
(C) Figure IIIG-11. FASOR Station THORN, Run 1, Source Depth = 23 Meters, Receiver Depth = 37 Meters, Frequency = 1500 Hertz



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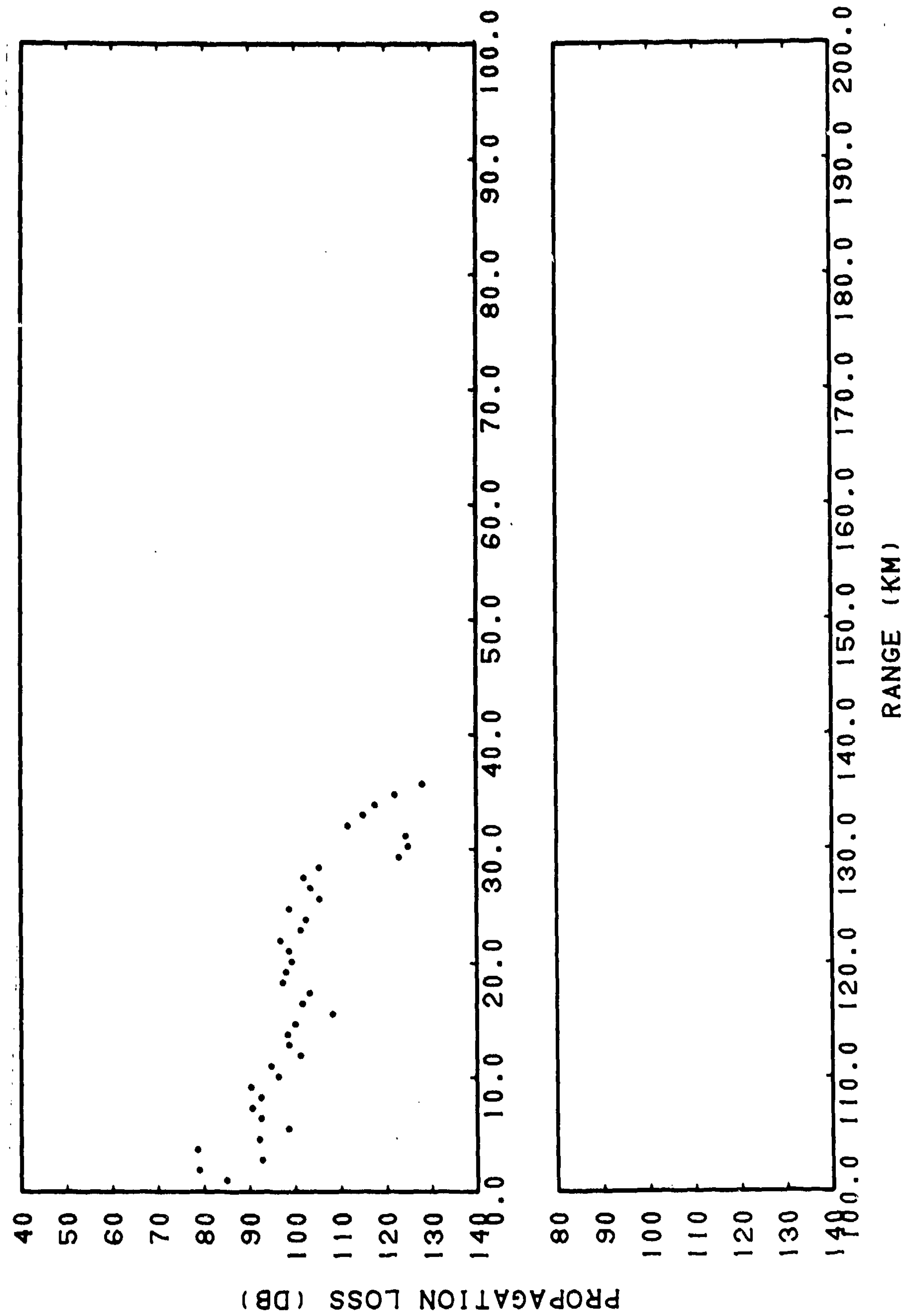
(C) Figure IIIG-12. FASOR Station THORN, Run 2, Source Depth = 23 Meters, Receiver Depth = 37 Meters, Frequency = 1500 Hertz



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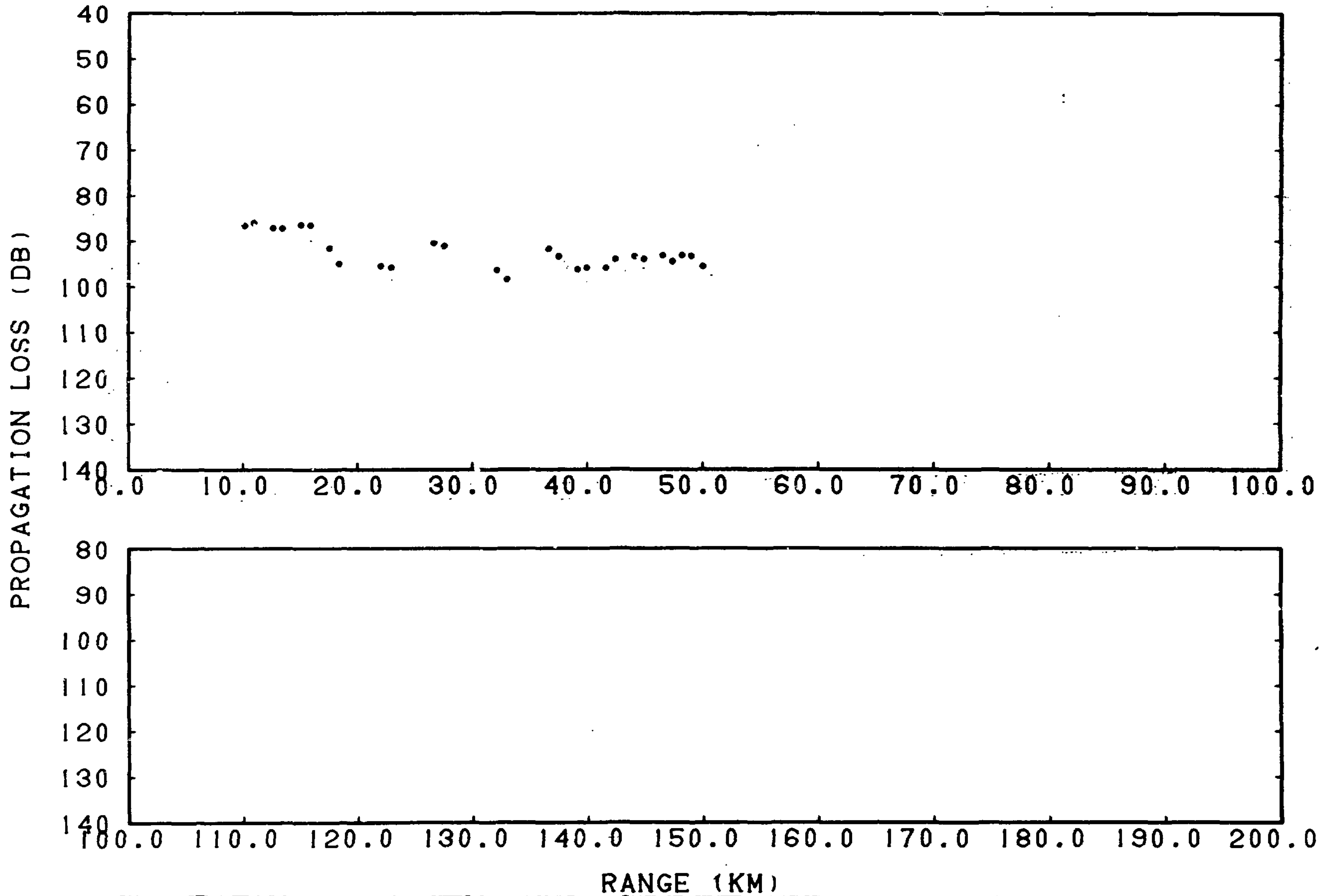
(C) Figure IIIG-13. FASOR Station REDWOOD, Run 3, Source Depth = 6.1 Meters, Receiver Depth = 37 Meters, Frequency = 1500 Hertz



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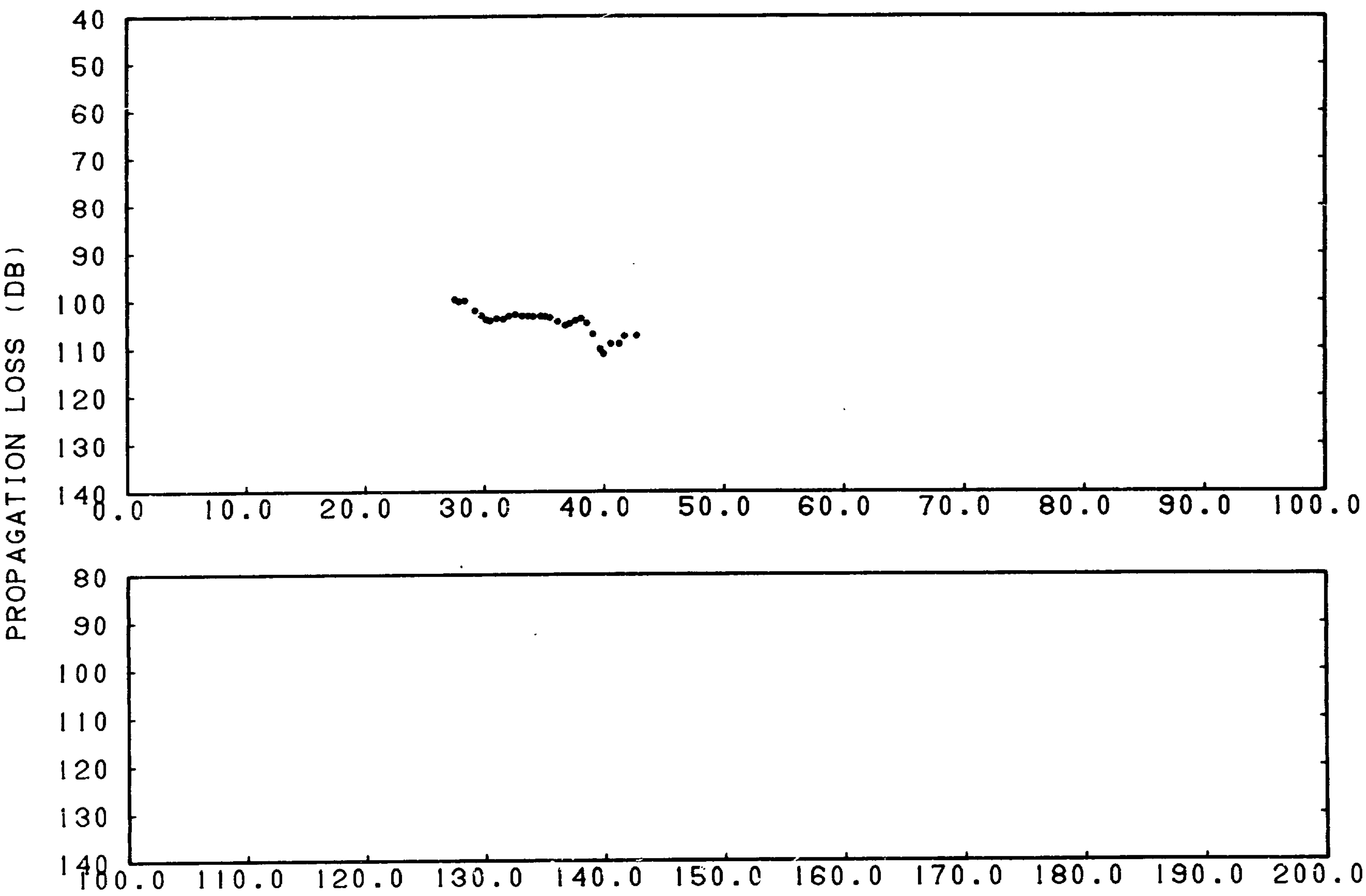
(C) Figure IIIG-14. Smoothed FASOR Station FIG, Run 3, Source Depth = 6.1 Meters, Receiver Depth = 37 Meters, Frequency = 1500 Hertz



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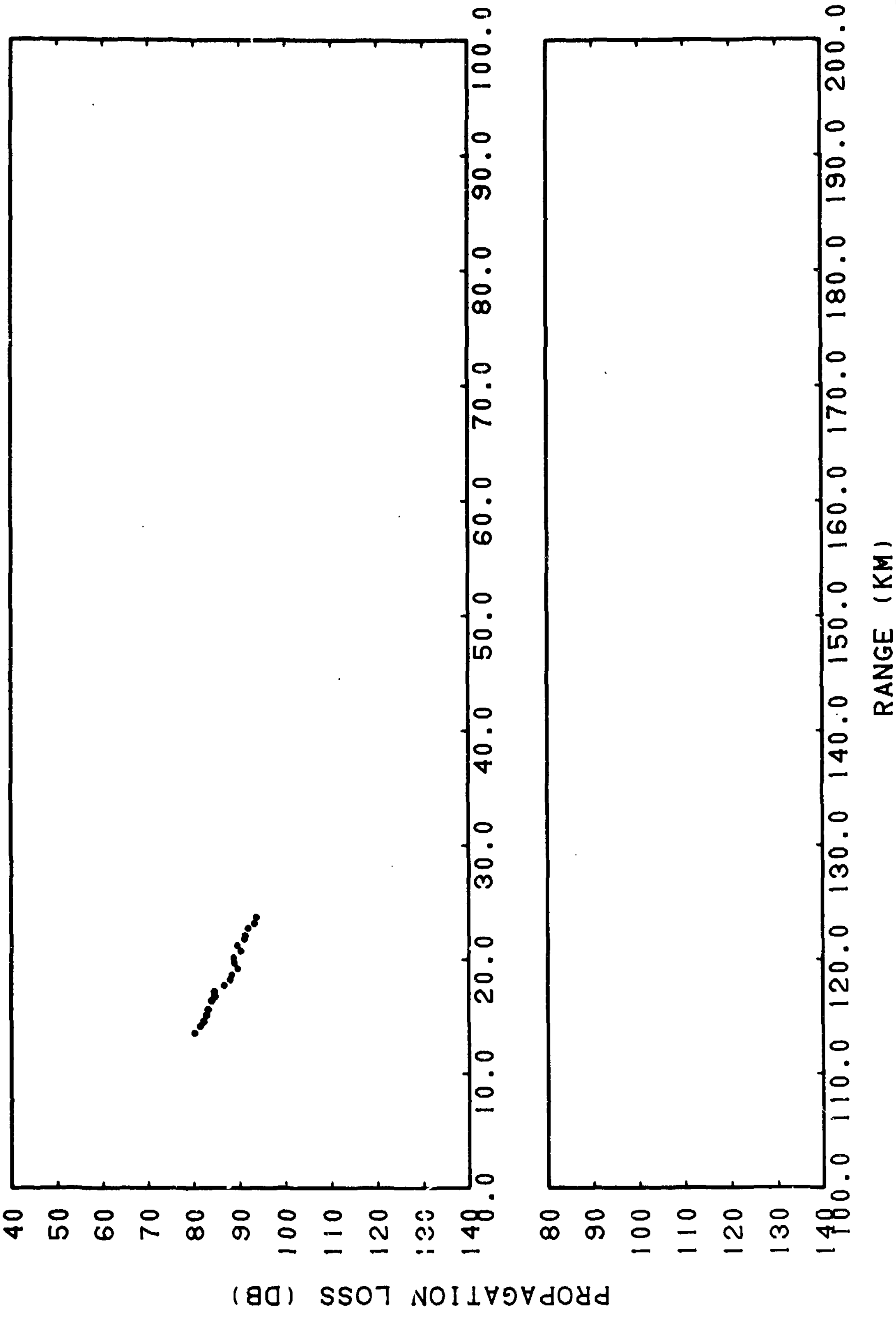
(C) Figure IIIG-15. Smoothed FASOR Station OAK, Run 1, Source Depth = 23 Meters, Receiver Depth = 37 Meters, Frequency = 1500 Hertz



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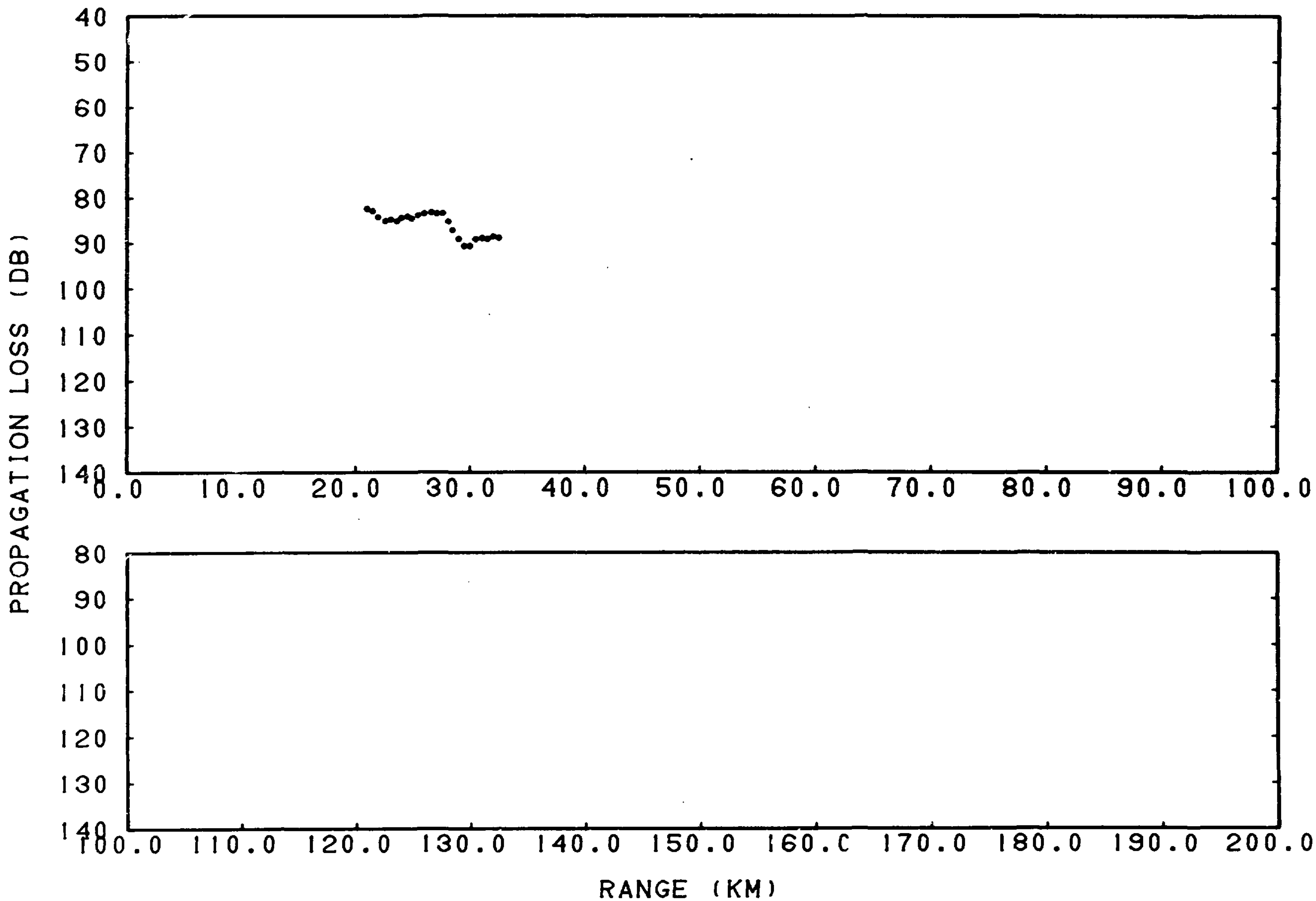
(C) Figure IIIG-16. Smoothed FASOR Station OAK, Run 2, Source Depth = 23 Meters, Receiver Depth = 37 Meters, Frequency = 1500 Hertz



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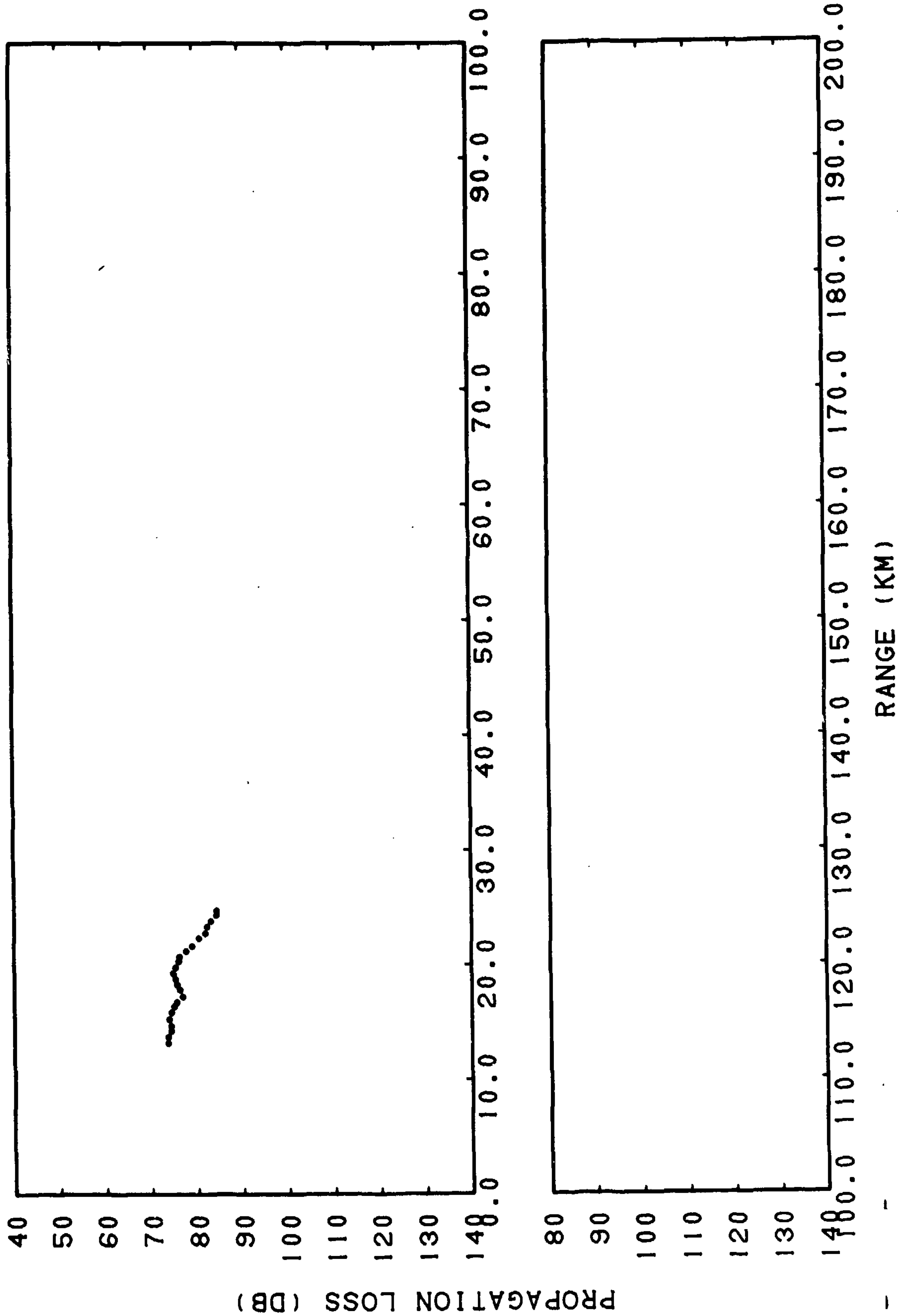
(C) Figure IIIG-17. Smoothed FASOR Station THORN, Run 1, Source Depth = 23 Meters, Receiver Depth = 37 Meters, Frequency = 1500 Hertz



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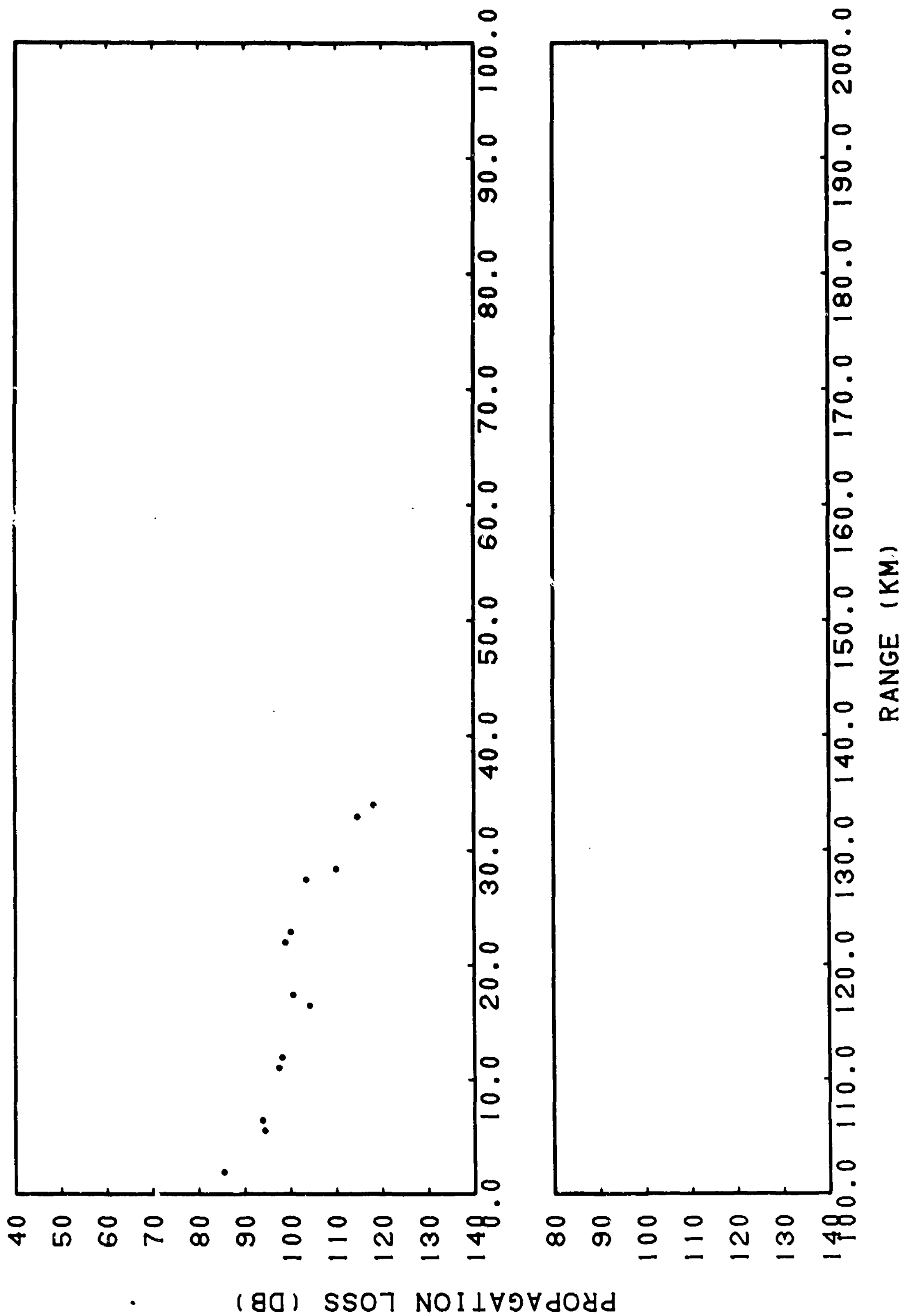
(C) Figure IIIG-18. Smoothed FASOR Station THORN, Run 2, Source Depth = 23 Meters, Receiver Depth = 37 Meters, Frequency = 1500 Hertz



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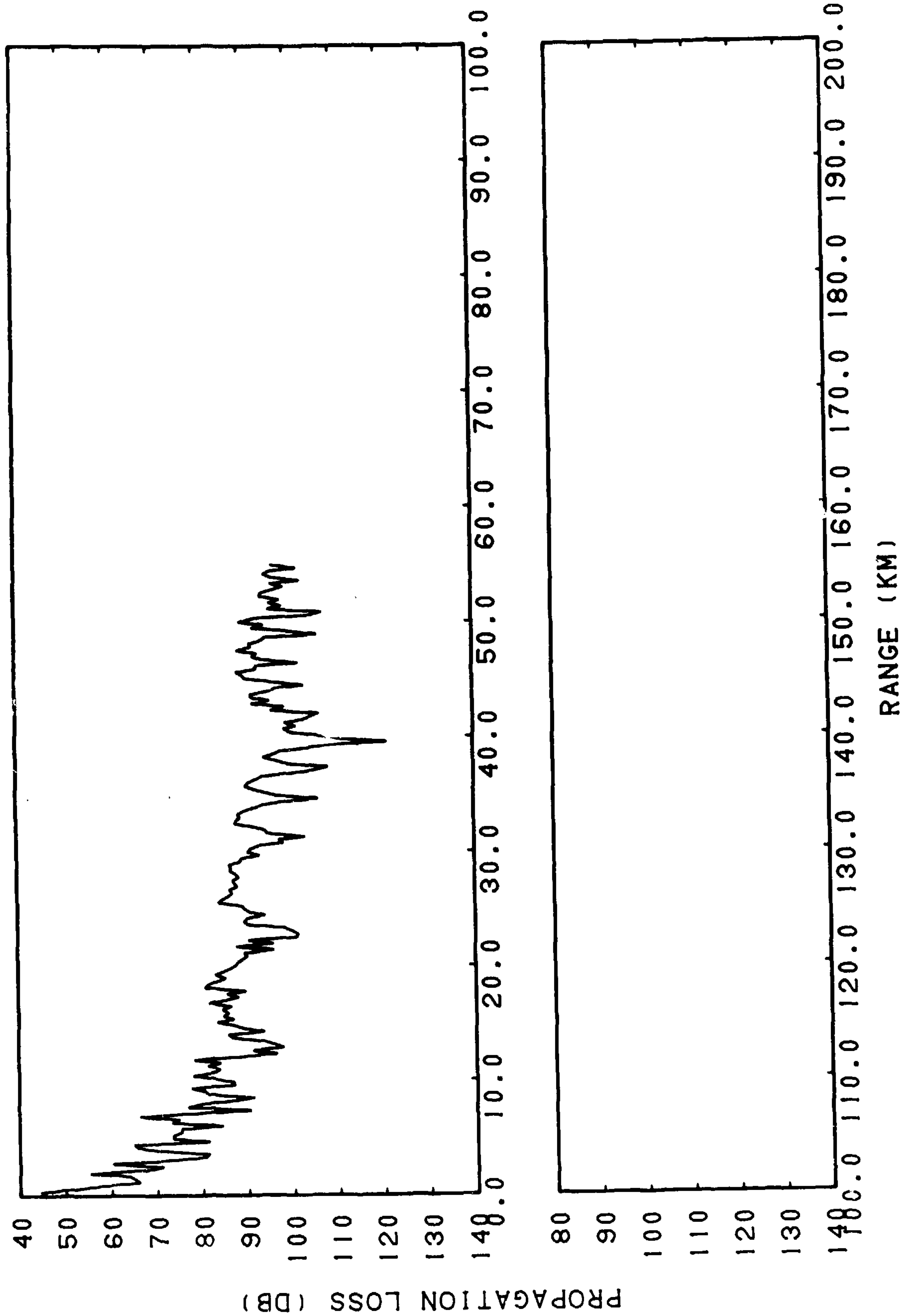
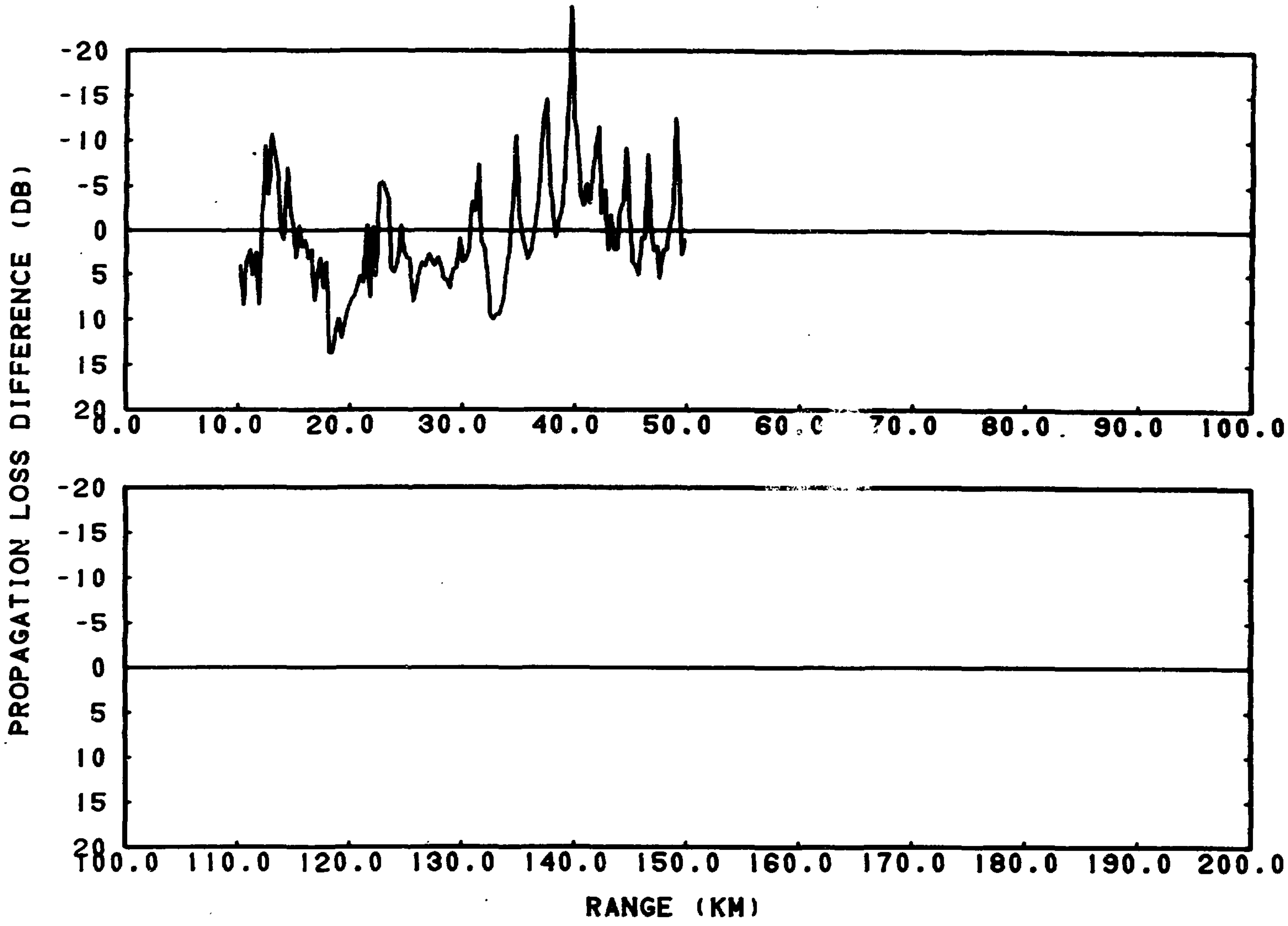
(C) Figure IIIG-19. Smoothed FASCR Station REDWOOD, Run 3, Source Depth = 6.1 Meters, Receiver Depth = 37 Meters, Frequency = 1500 Hertz



(C) Figure IIIG-20. RAYMODE Coherent, Station FIG, Run 3, Source Depth = 6.1 Meters, Receiver Depth = 37 Meters, Frequency = 1500 Hertz



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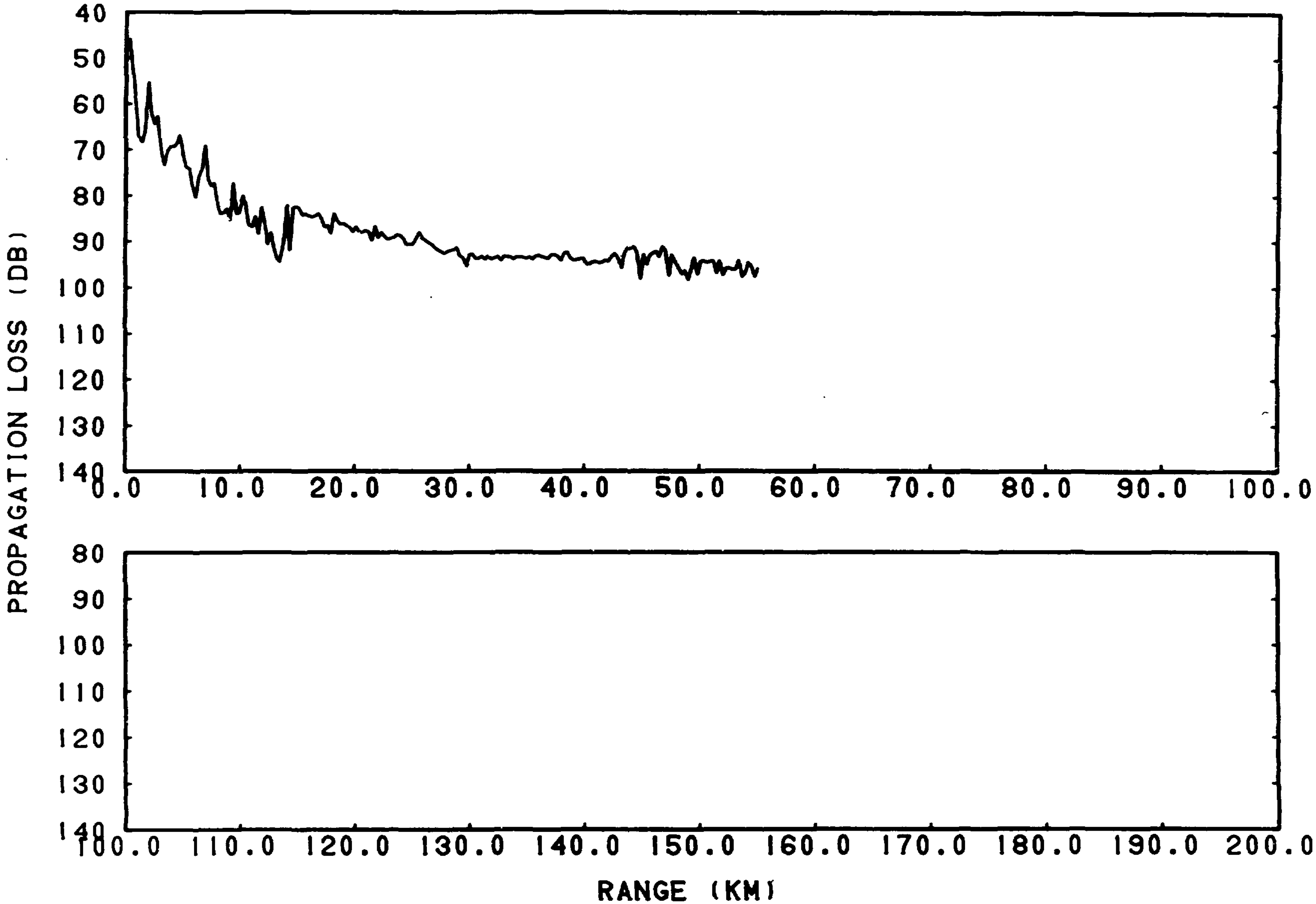
(C) Figure IIIG-21. RAYMODE Coherent, Station FIG, Run 3, Source Depth 6.1 Meters, Receiver Depth = 37 Meters, Frequency = 1500 Hertz, Subtracted from Smoothed FASOR, Station FIG, Run 3, Source Depth = 6.1 Meters, Receiver Depth = 37 Meters, Frequency = 1500 Hertz



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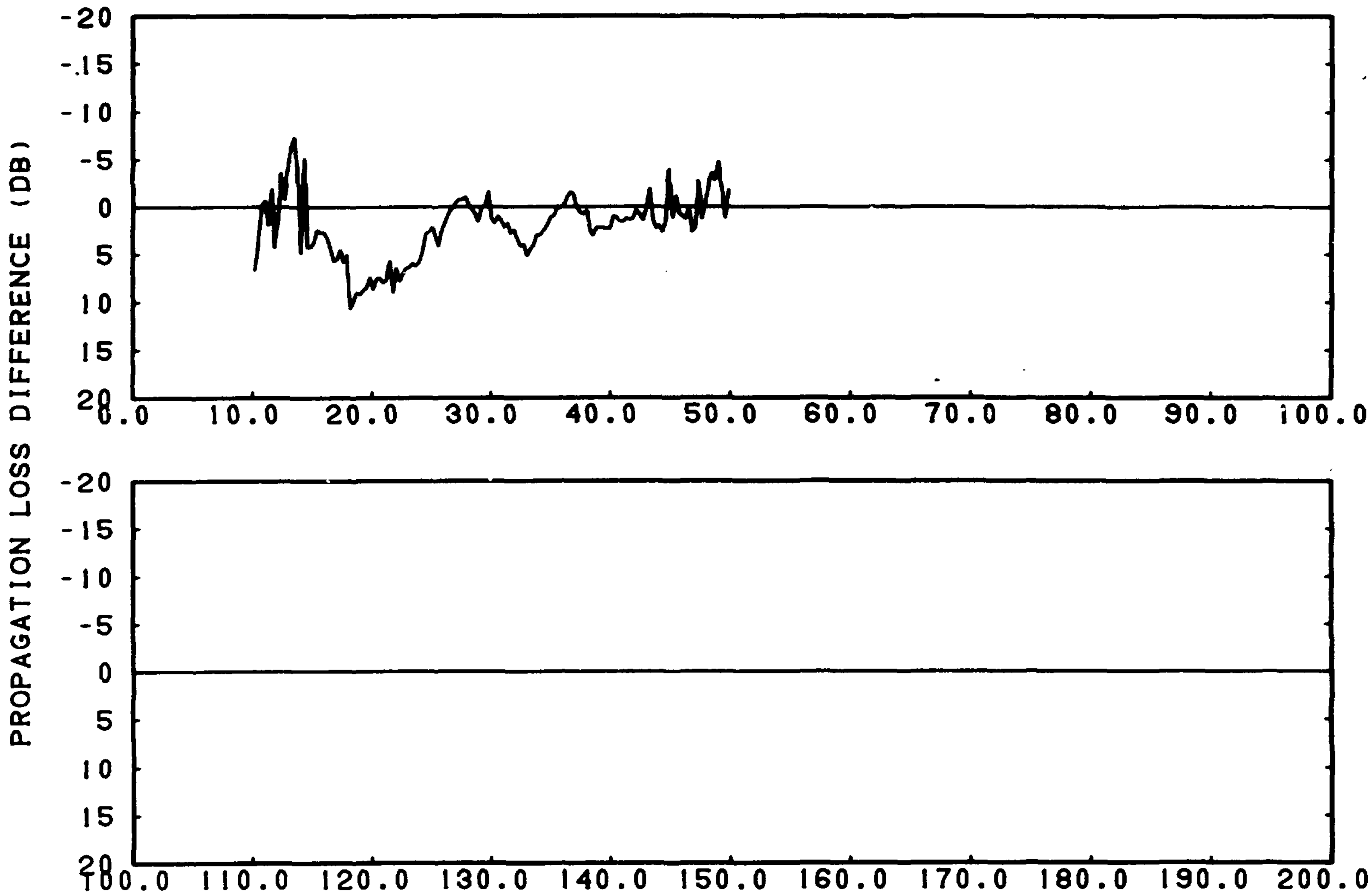
(C) Figure IIIG-22. RAYMODE Incoherent, Station FIG, Run 3, Source Depth = 6.1 Meters, Receiver Depth = 37 Meters, Frequency = 1500 Hertz



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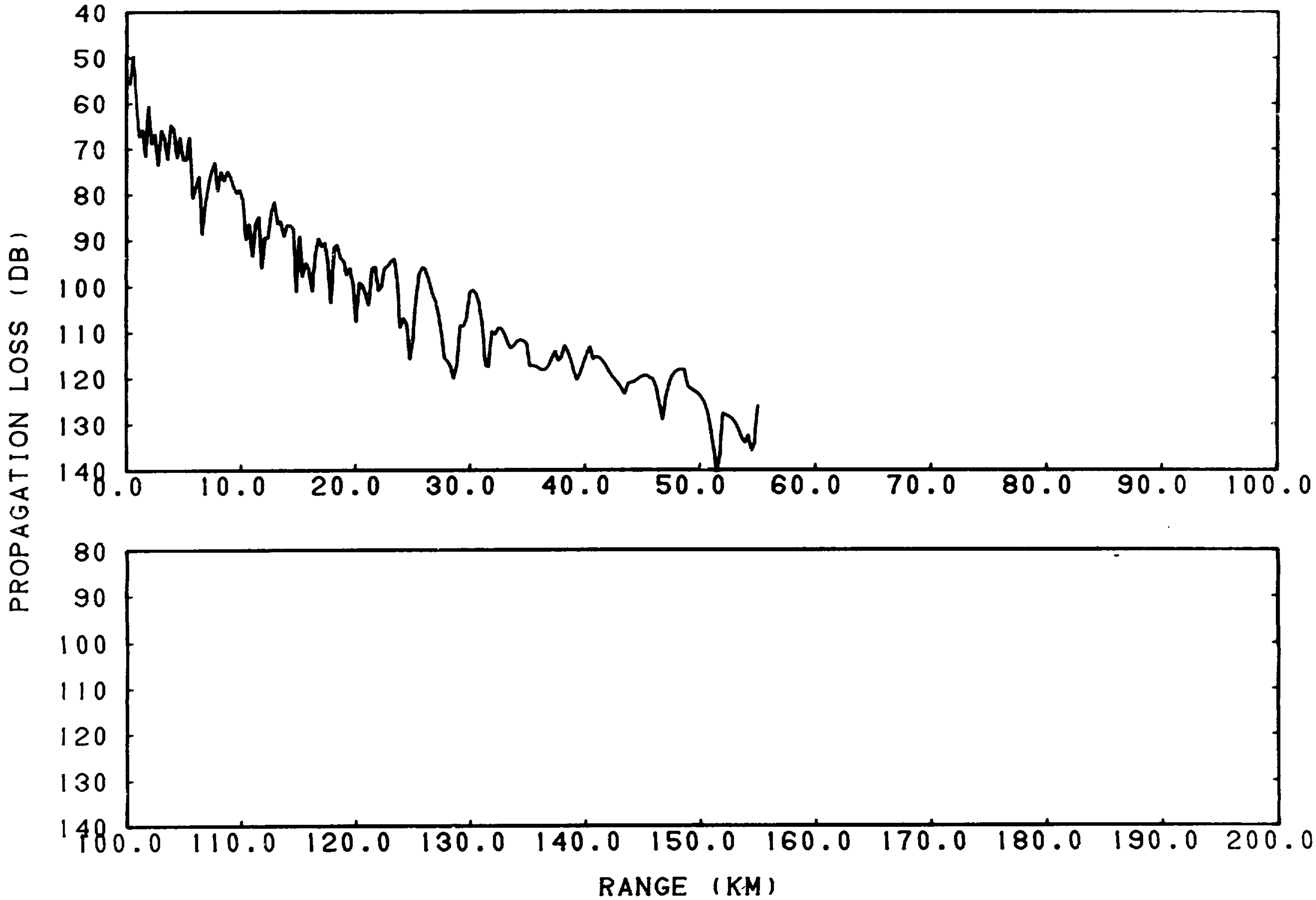
(C) Figure IIIG-23. RAYMODE Incoherent, Station FIG, Run 3, Source Depth = 6.1 Meters, Receiver Depth = 37 Meters, Frequency = 1500 Hertz, Subtracted from Smoothed FASOR, Station FIG, Run 3, Source Depth = 6.1 Meters, Receiver Depth = 37 Meters, Frequency = 1500 Hertz



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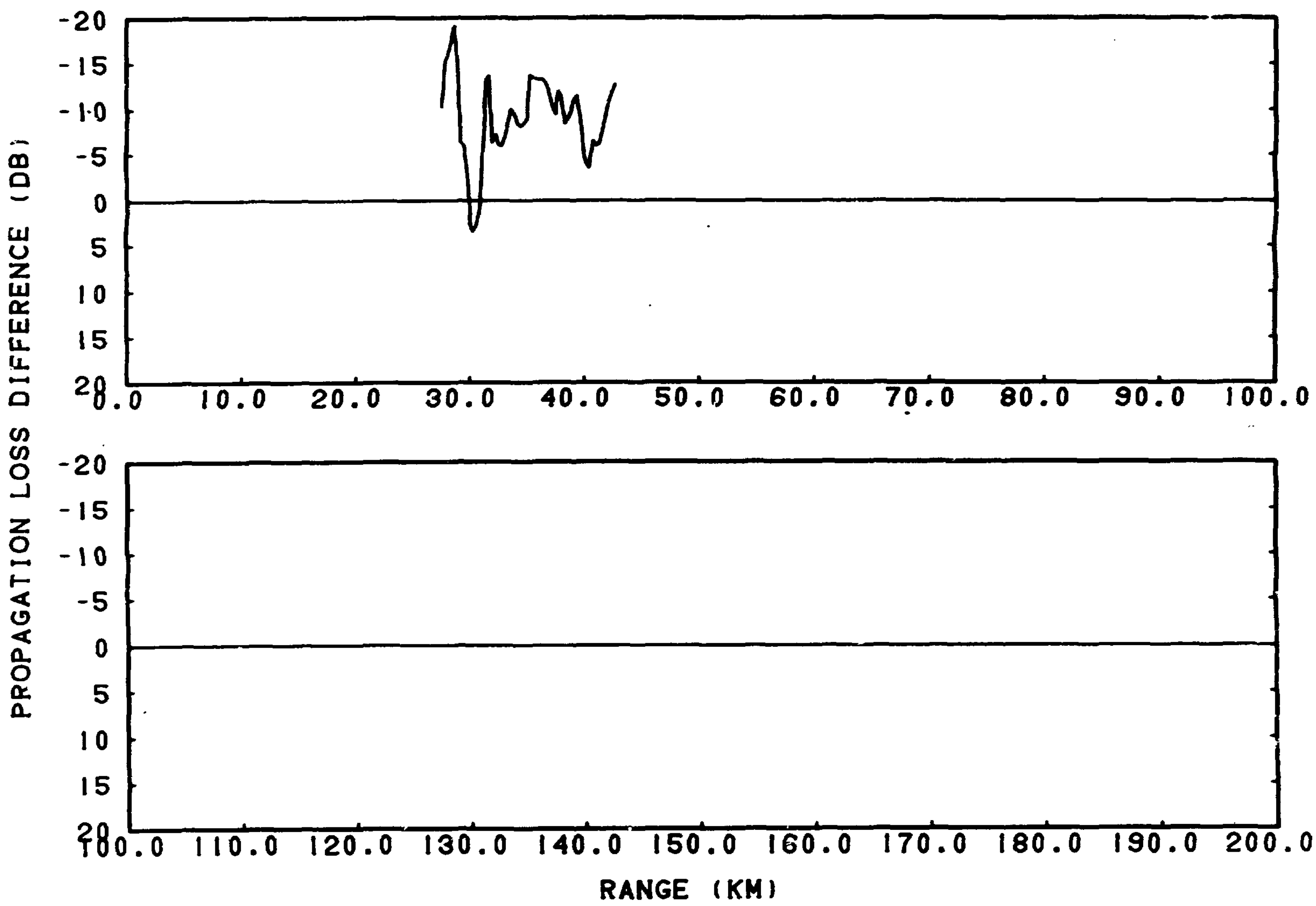
(C) Figure IIIG-24. RAYMODE Coherent, Station OAK, Run 1, Source Depth = 23 Meters, Receiver Depth = 37 Meters, Frequency = 1500 Hertz



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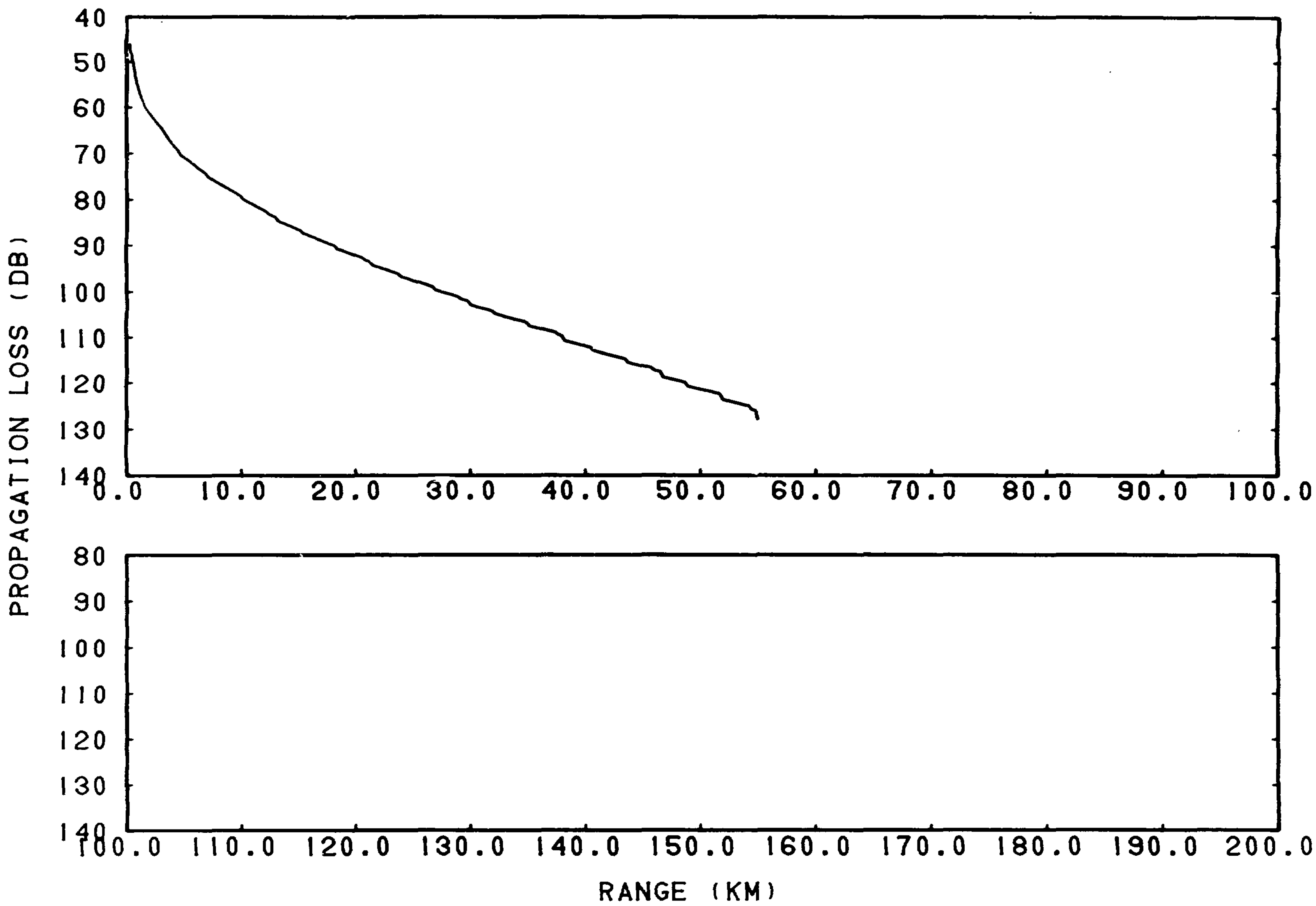
(C) Figure IIIG-25. RAYMODE Coherent, Station OAK, Run 1, Source Depth = 23 Meters, Receiver Depth = 37 Meters, Frequency = 1500 Hertz, Subtracted from Smoothed FASOR, Station OAK, Run 1, Source Depth = 23 Meters, Receiver Depth = 37 Meters, Frequency = 1500 Hertz



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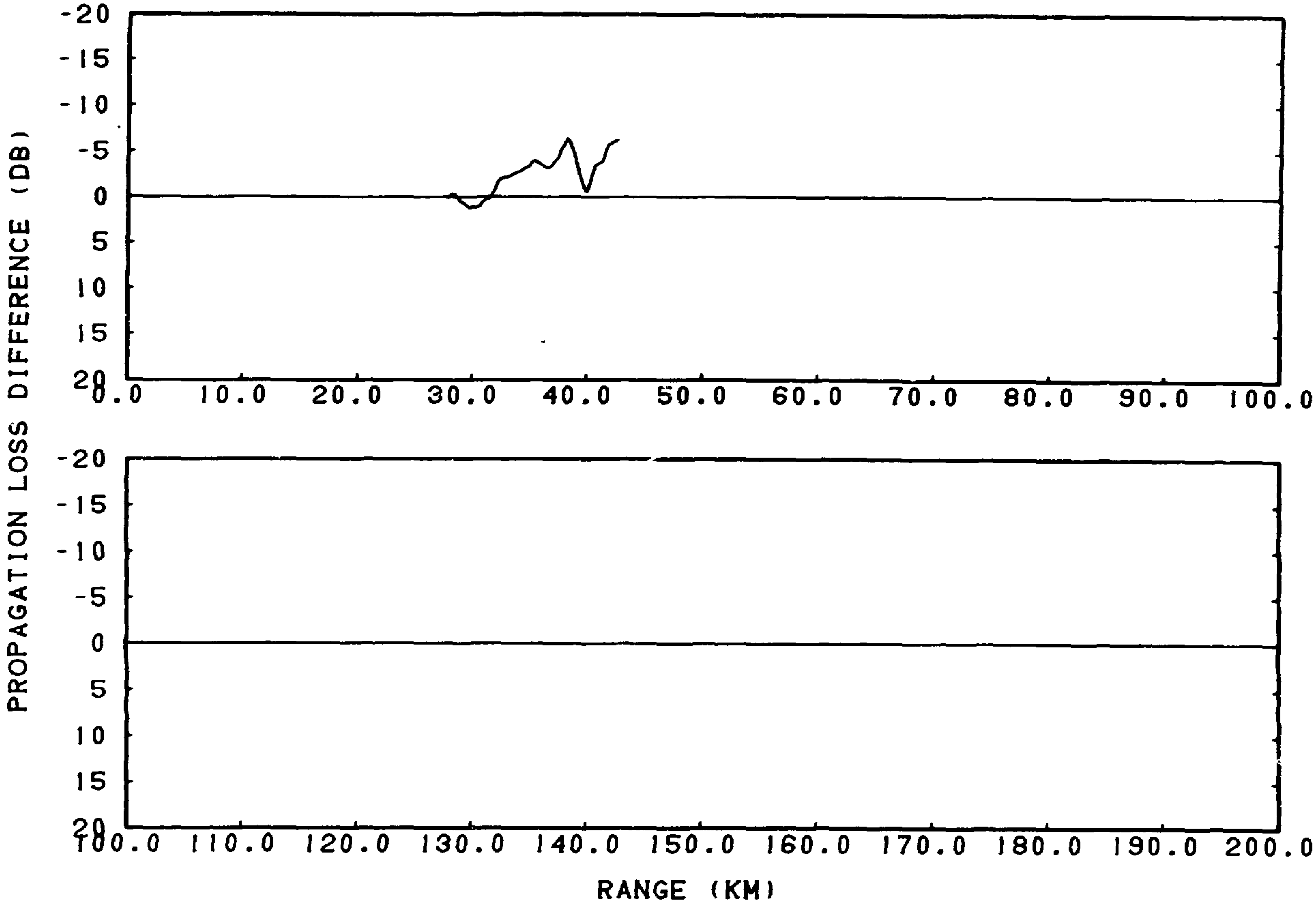
(C) Figure IIIG-26. RAYMODE Incoherent, Station OAK, Run 1, Source Depth = 23 Meters, Receiver Depth = 37 Meters, Frequency = 1500 Hertz



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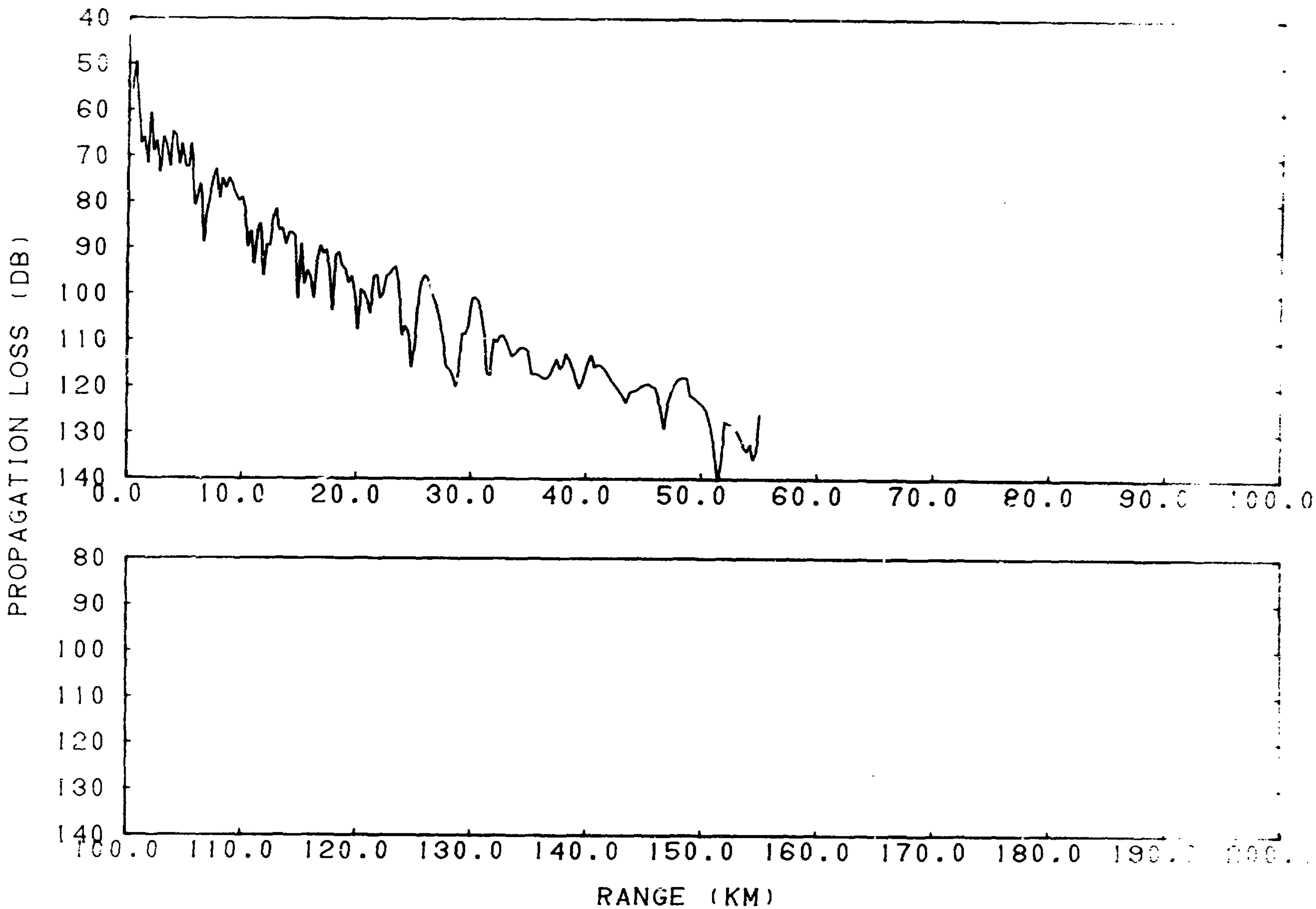
(C) Figure IIIG-27. RAYMODE Incoherent, Station OAK, Run 1, Source Depth = 23 Meters, Receiver Depth = 37 Meters, Frequency = 1500 Hertz, Subtracted from Smoothed FASOR, Station OAK, Run 1, Source Depth = 23 Meters, Receiver Depth = 37 Meters, Frequency = 1500 Hertz



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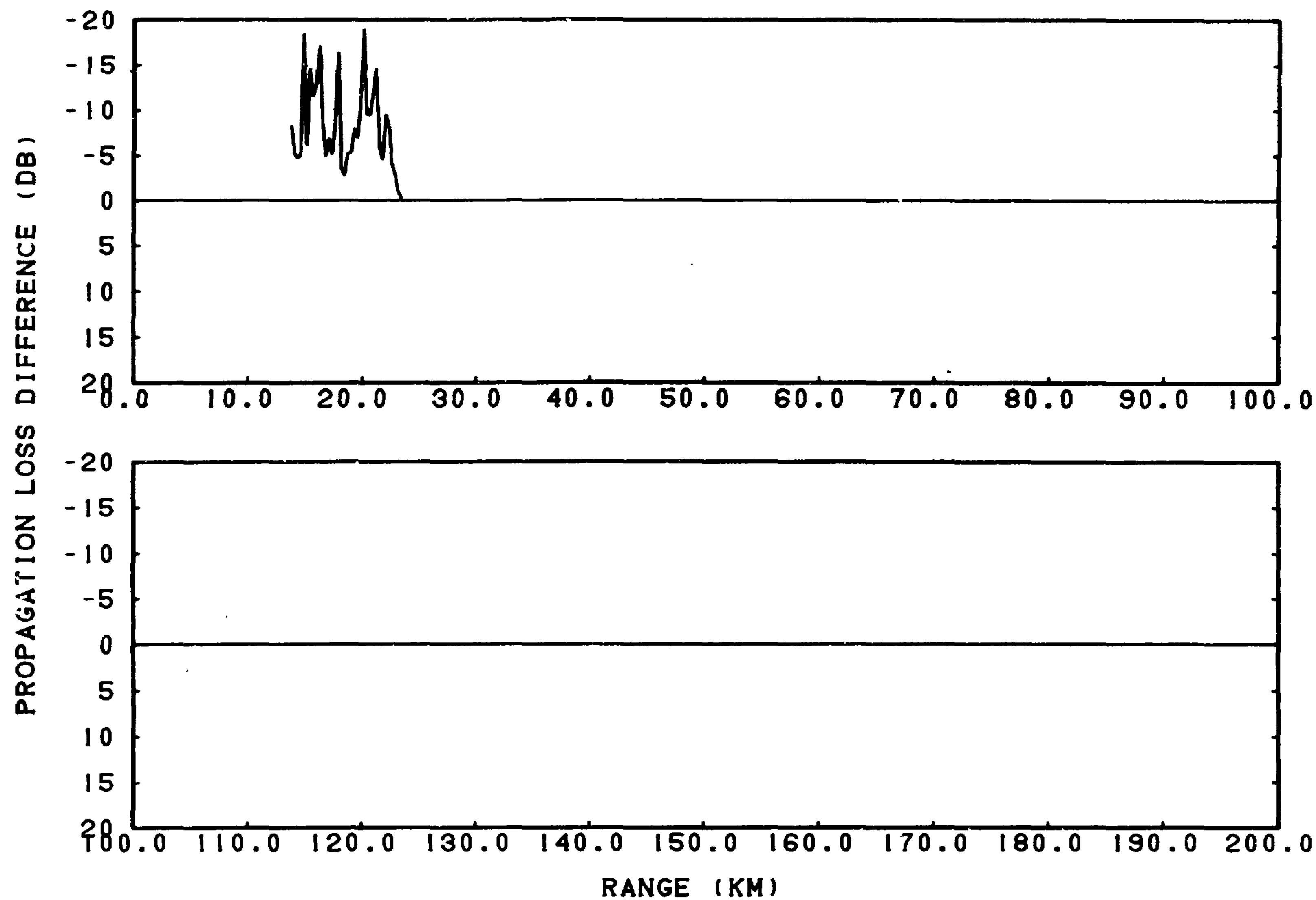
(C) Figure IIIG-28. RAYMODE Coherent, Station OAK, Run 2, Source Depth = 23 Meters, Receiver Depth = 37 Meters, Frequency = 1500 Hertz



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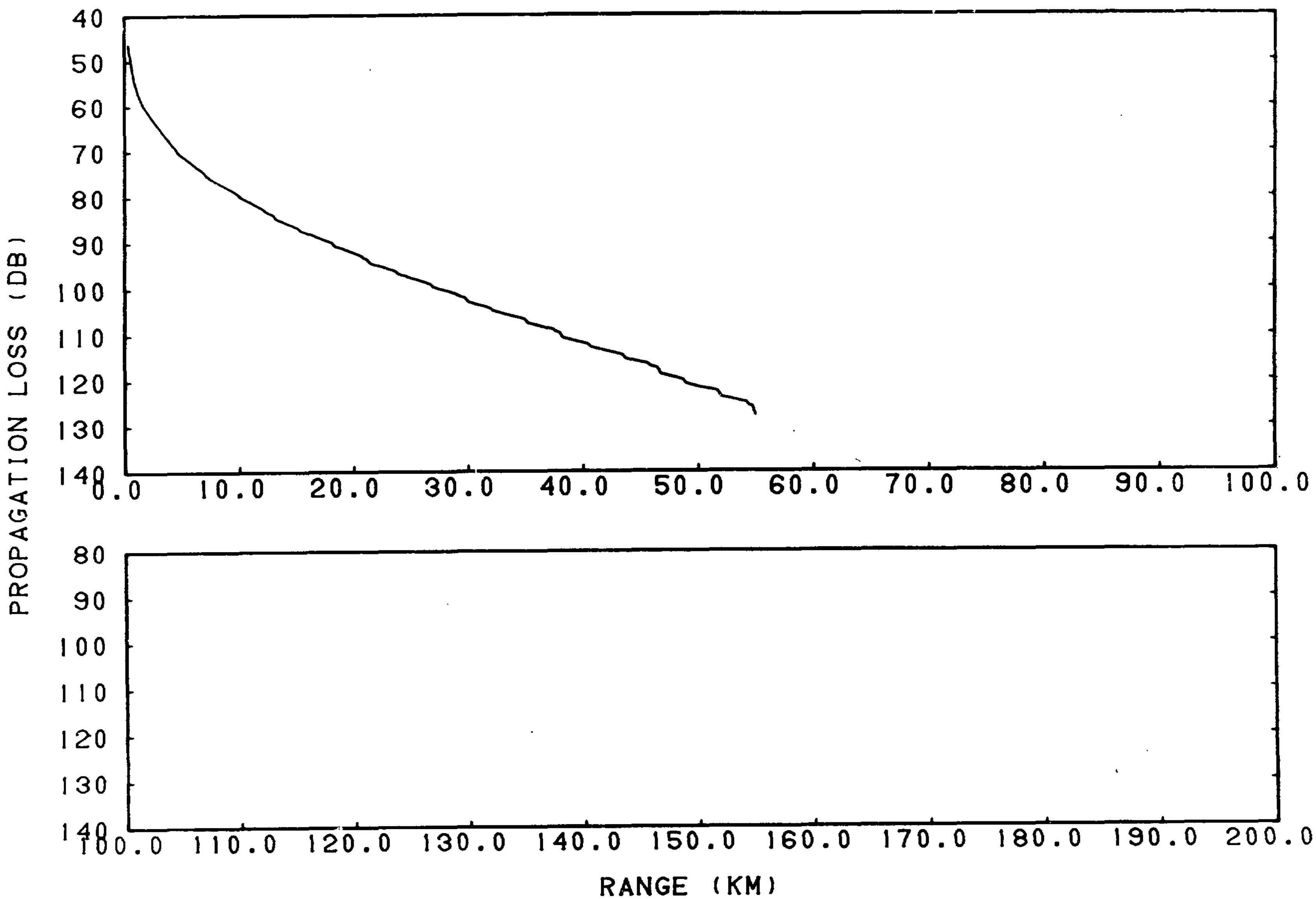
(C) Figure IIIG-29. RAYMODE Coherent, Station OAK, Run 2, Source Depth = 23 Meters, Receiver Depth = 37 Meters, Frequency = 1500 Hertz, Subtracted from Smoothed FASOR, Station OAK, Run 2, Source Depth = 23 Meters, Receiver Depth = 37 Meters, Frequency = 1500 Hertz



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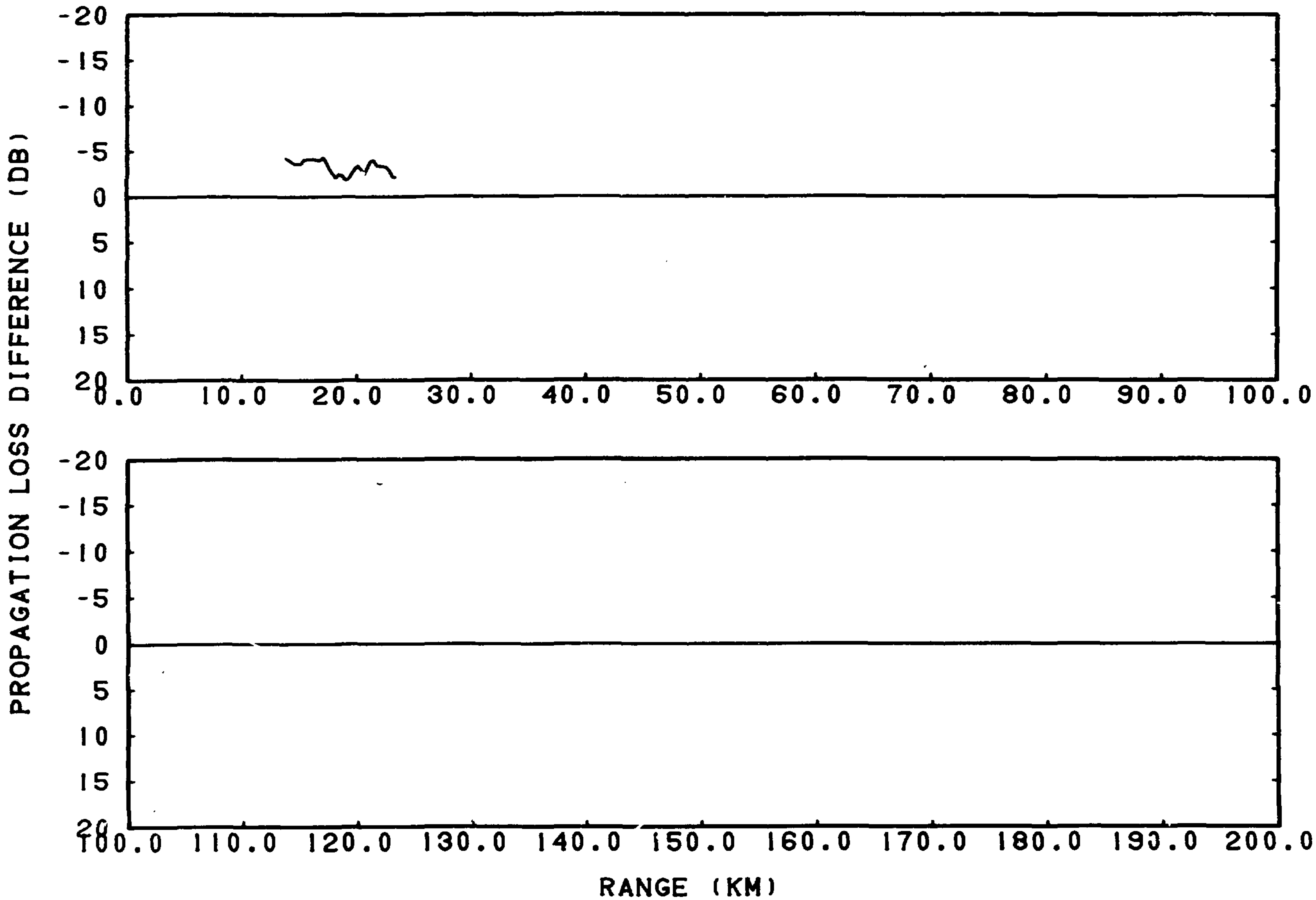
(C) Figure IIIG-30. RAYMODE Incoherent, Station OAK, Run 2, Source Depth = 23 Meters, Receiver Depth = 37 Meters, Frequency = 1500 Hertz



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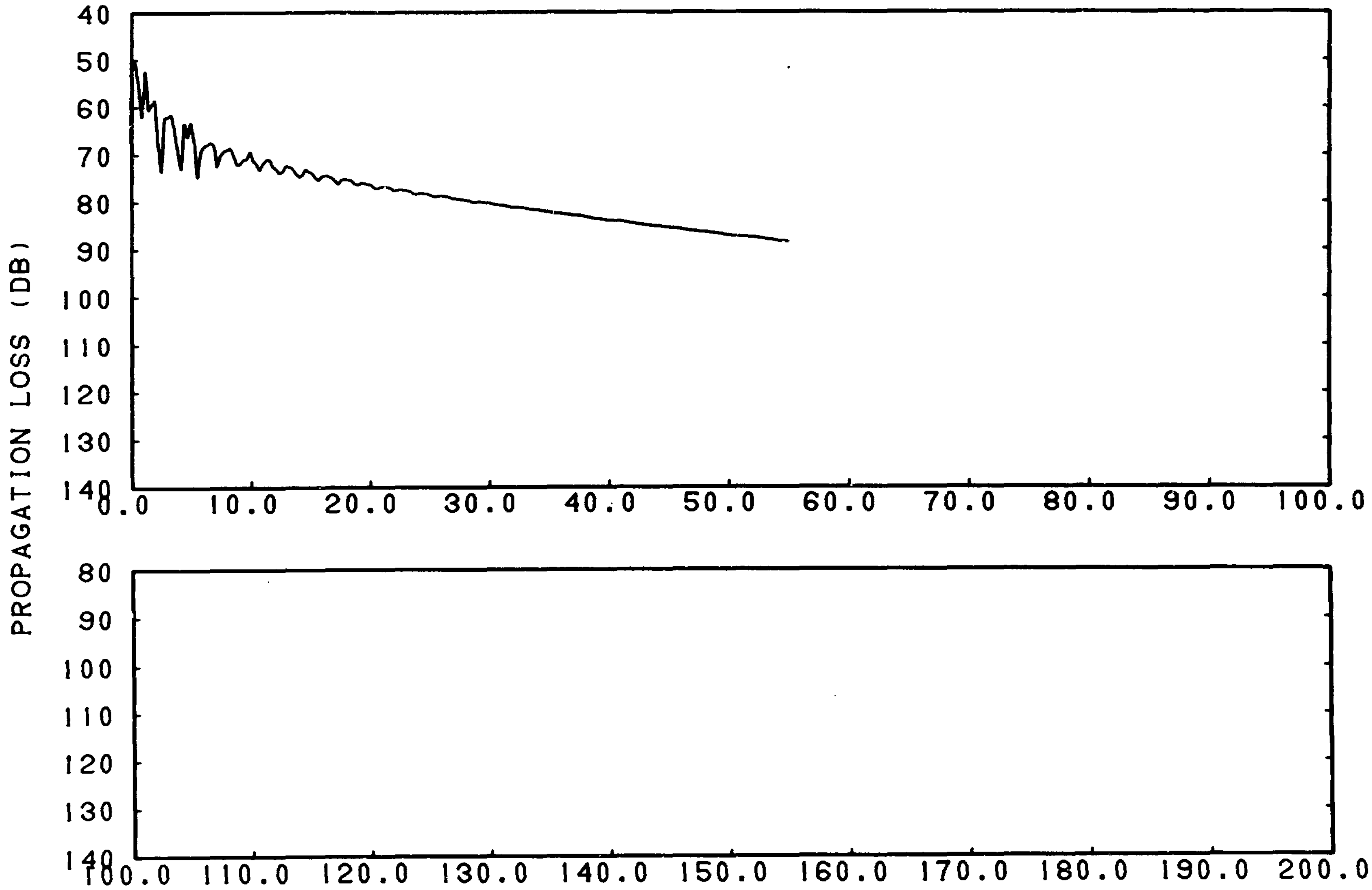
(C) Figure IIIG-31. RAYMODE Incoherent, Station OAK, Run 2, Source Depth = 23 Meters, Receiver Depth = 37 Meters, Frequency = 1500 Hertz, Subtracted from Smoothed FASOR, Station OAK, Run 2, Source Depth = 23 Meters, Receiver Depth = 37 Meters, Frequency = 1500 Hertz



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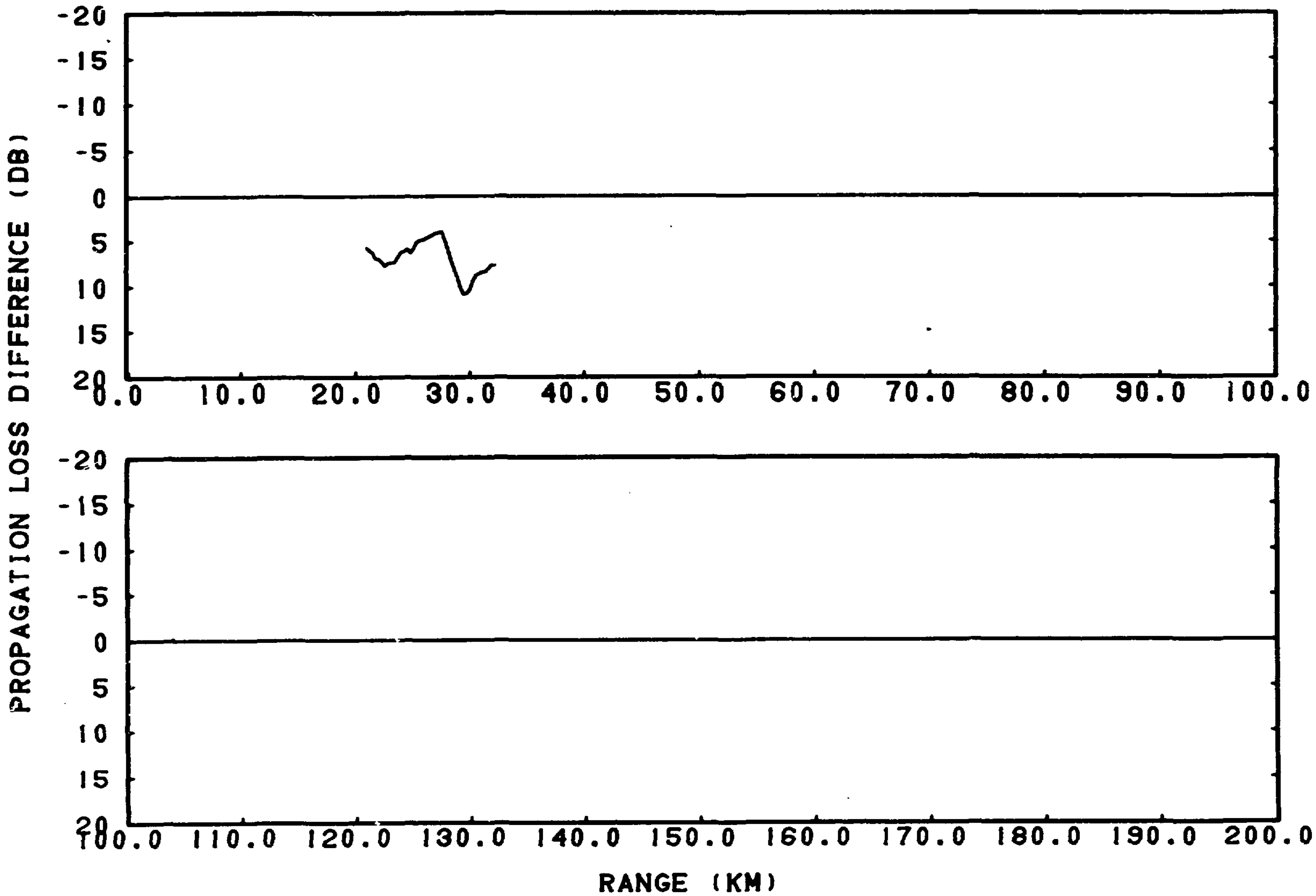
(C) Figure IIIG-32. RAYMODE Coherent, Station THORN, Run 1, Source Depth = 23 Meters, Receiver Depth = 37 Meters, Frequency = 1500 Hertz



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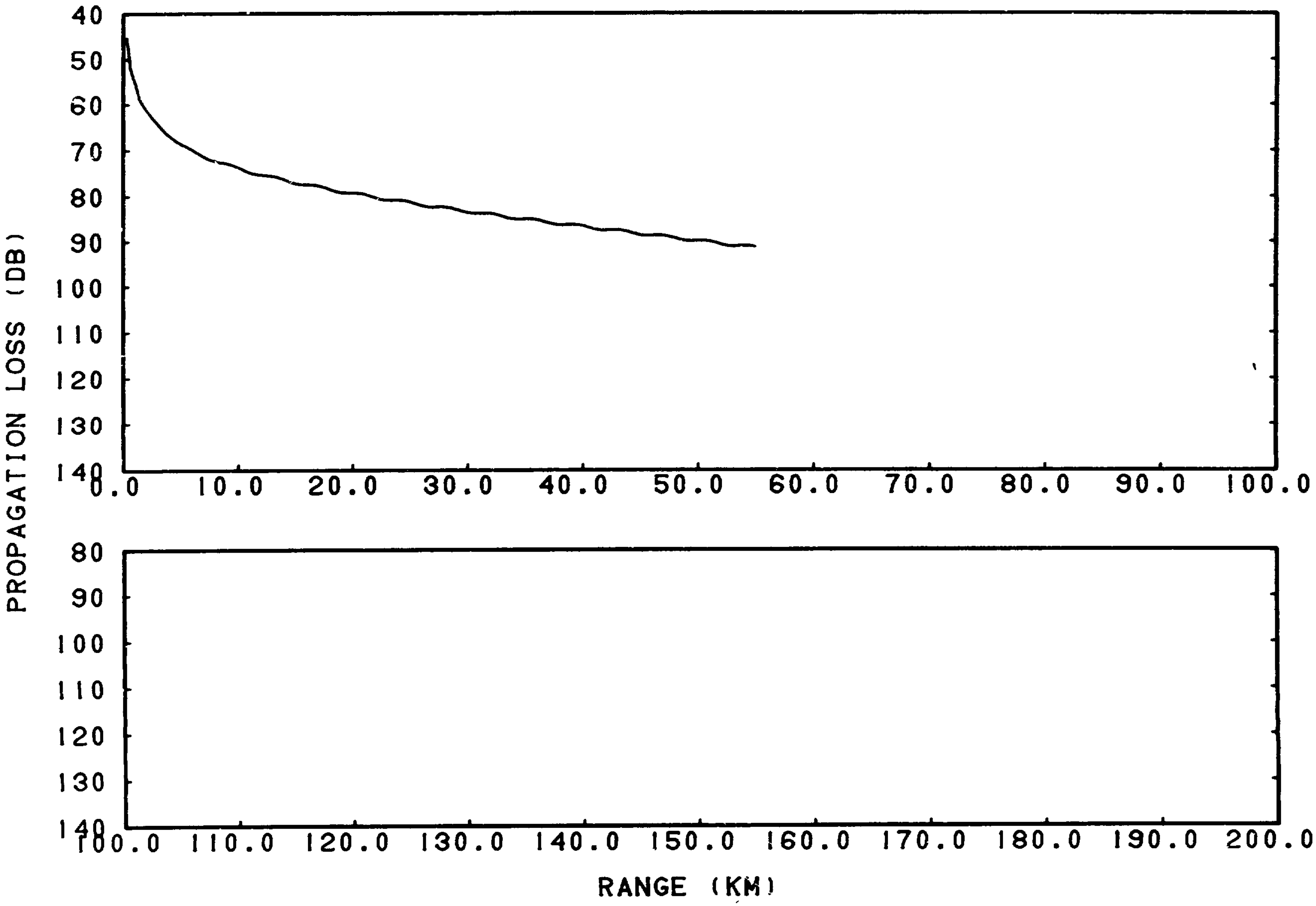
(C) Figure IIIG-33. RAYMODE Coherent, Station THORN, Run 1, Source Depth = 23 Meters, Receiver Depth = 37 Meters, Frequency = 1500 Hertz, Subtracted from Smoothed FASOR, Station THORN, Run 1, Source Depth = 23 Meters, Receiver Depth = 37 Meters, Frequency = 1500 Hertz



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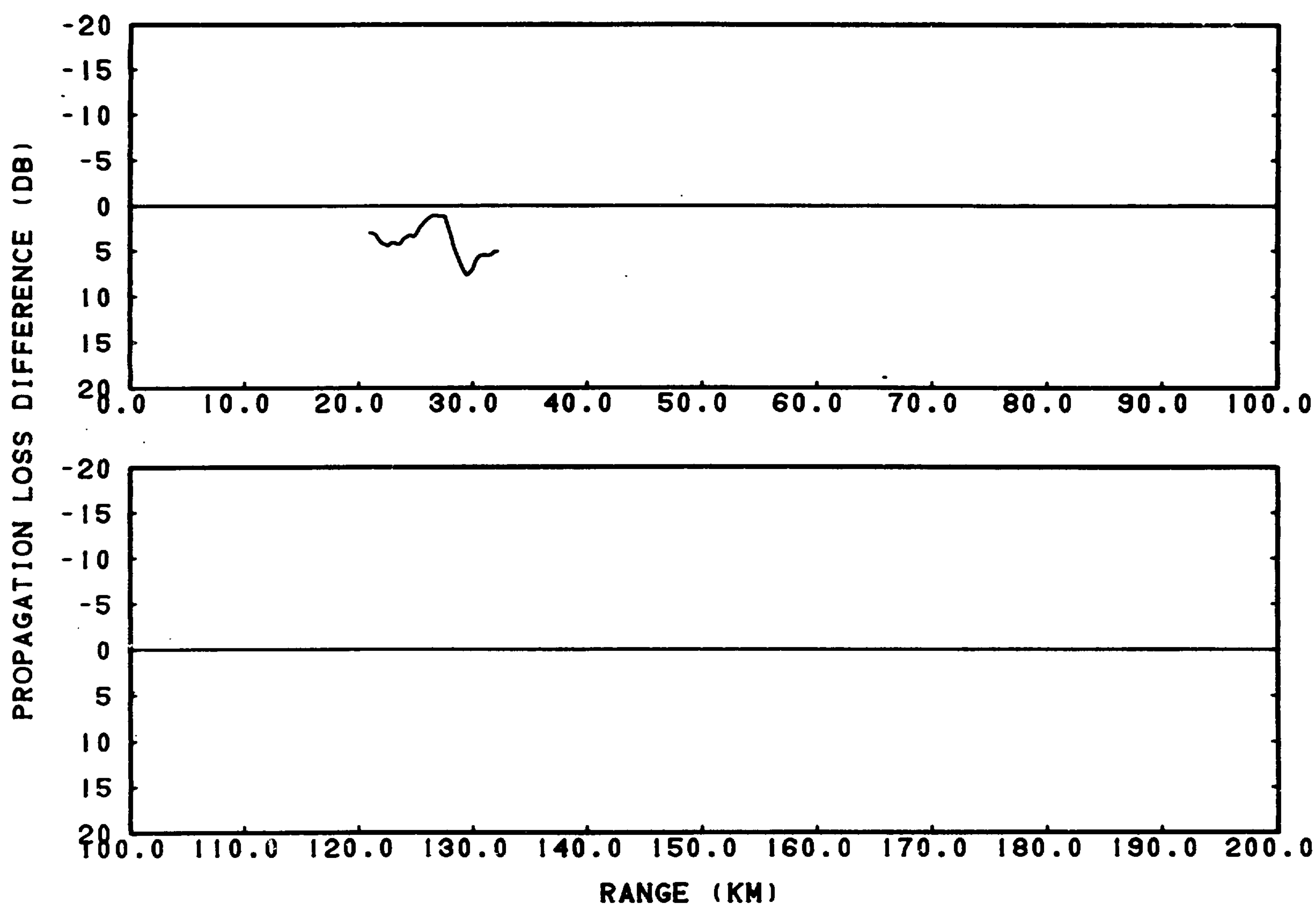
(C) Figure IIIG-34. RAYMODE Incoherent, Station THORN, Run 1, Source Depth = 23 Meters, Receiver Depth = 37 Meters, Frequency = 1500 Hertz



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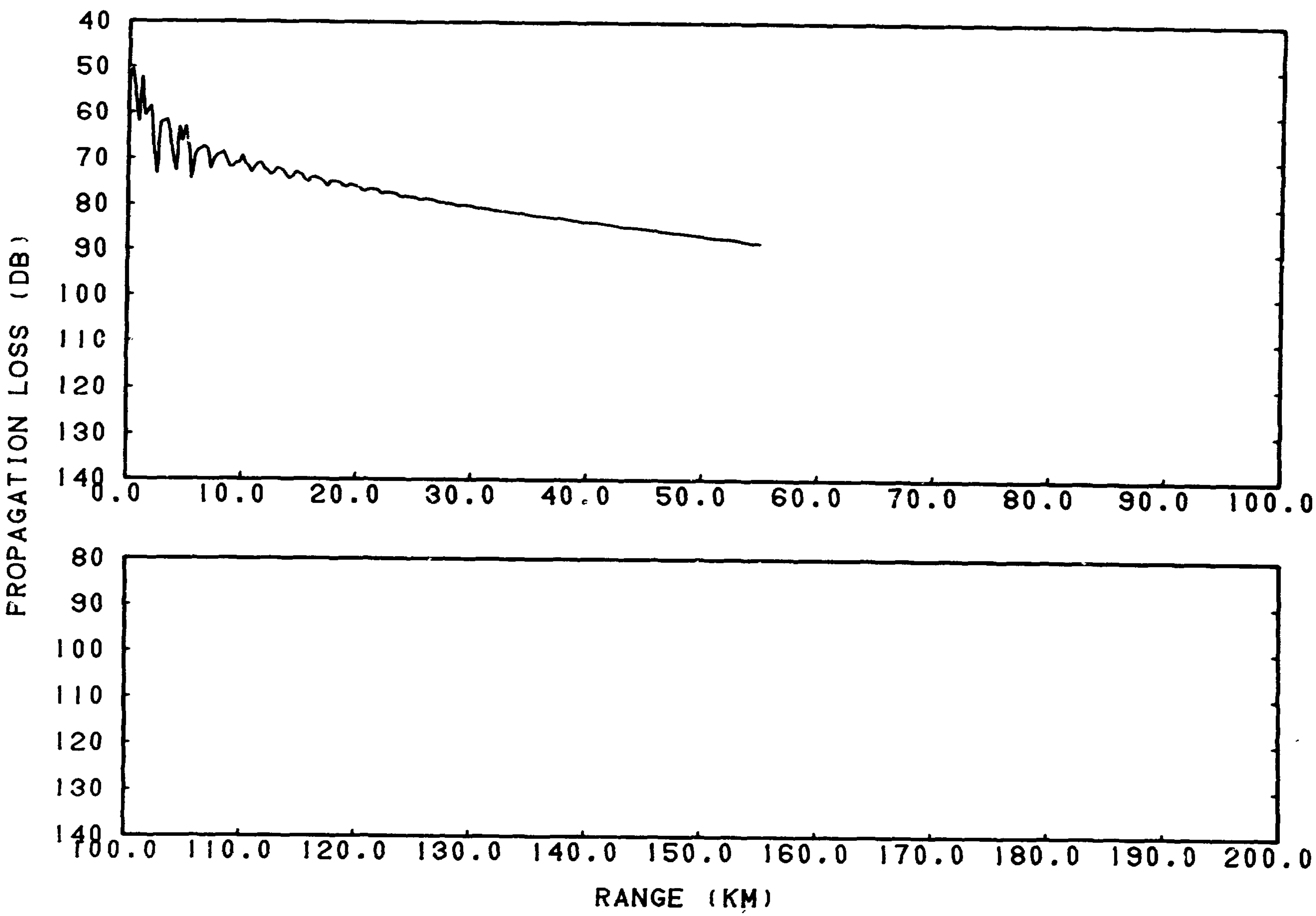
(C) Figure IIIG-35. RAYMODE Incoherent, Station THORN, Run 1, Source Depth = 23 Meters, Receiver Depth = 37 Meters, Frequency = 1500 Hertz, Subtracted from Smoothed FASOR, Station THORN, Run 1, Source Depth = 23 Meters, Receiver Depth = 37 Meters, Frequency = 1500 Hertz



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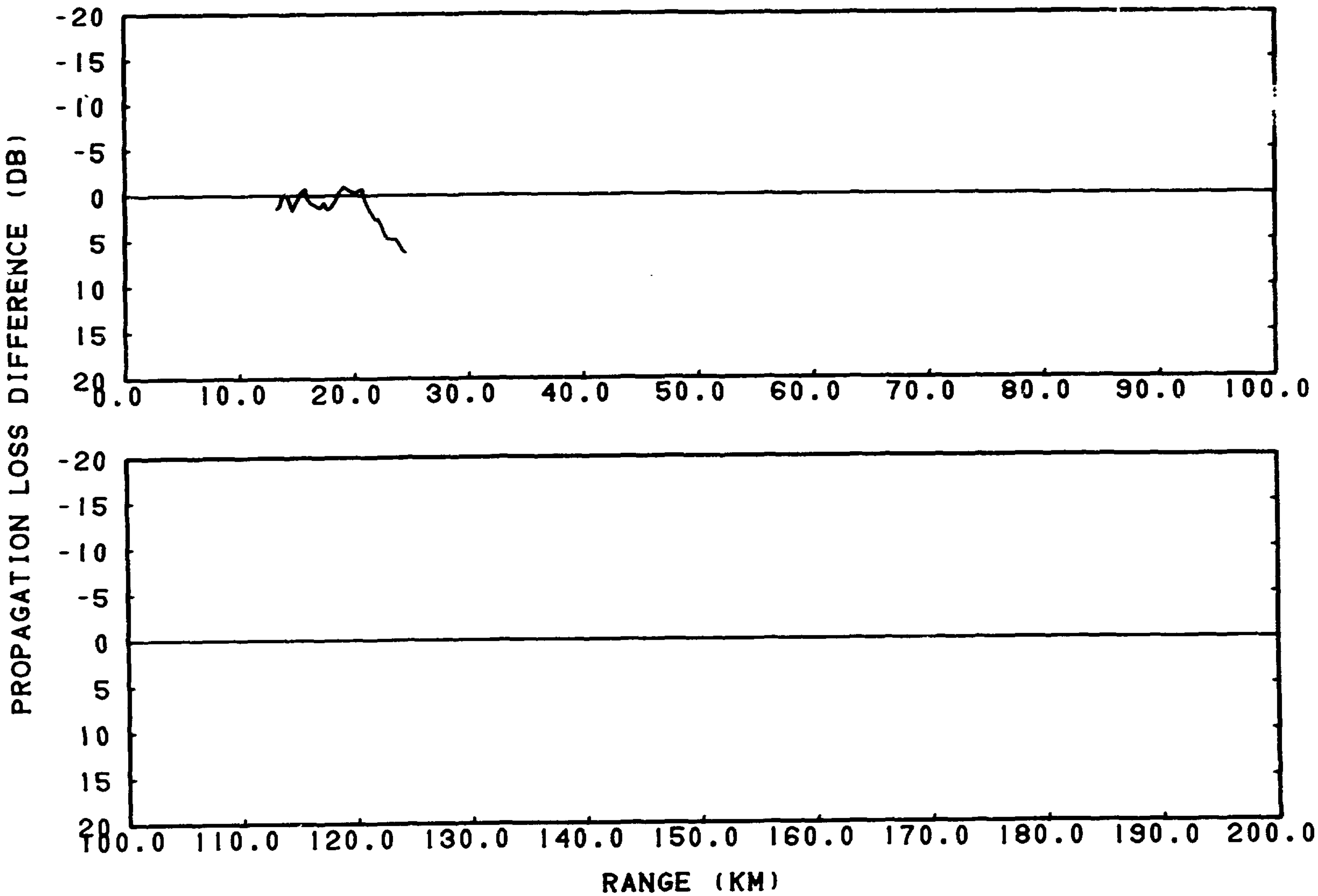
(C) Figure IIIG-36. RAYMODE Coherent, Station THORN, Run 2, Source Depth = 23 Meters, Receiver Depth = 37 Meters, Frequency = 1500 Hertz



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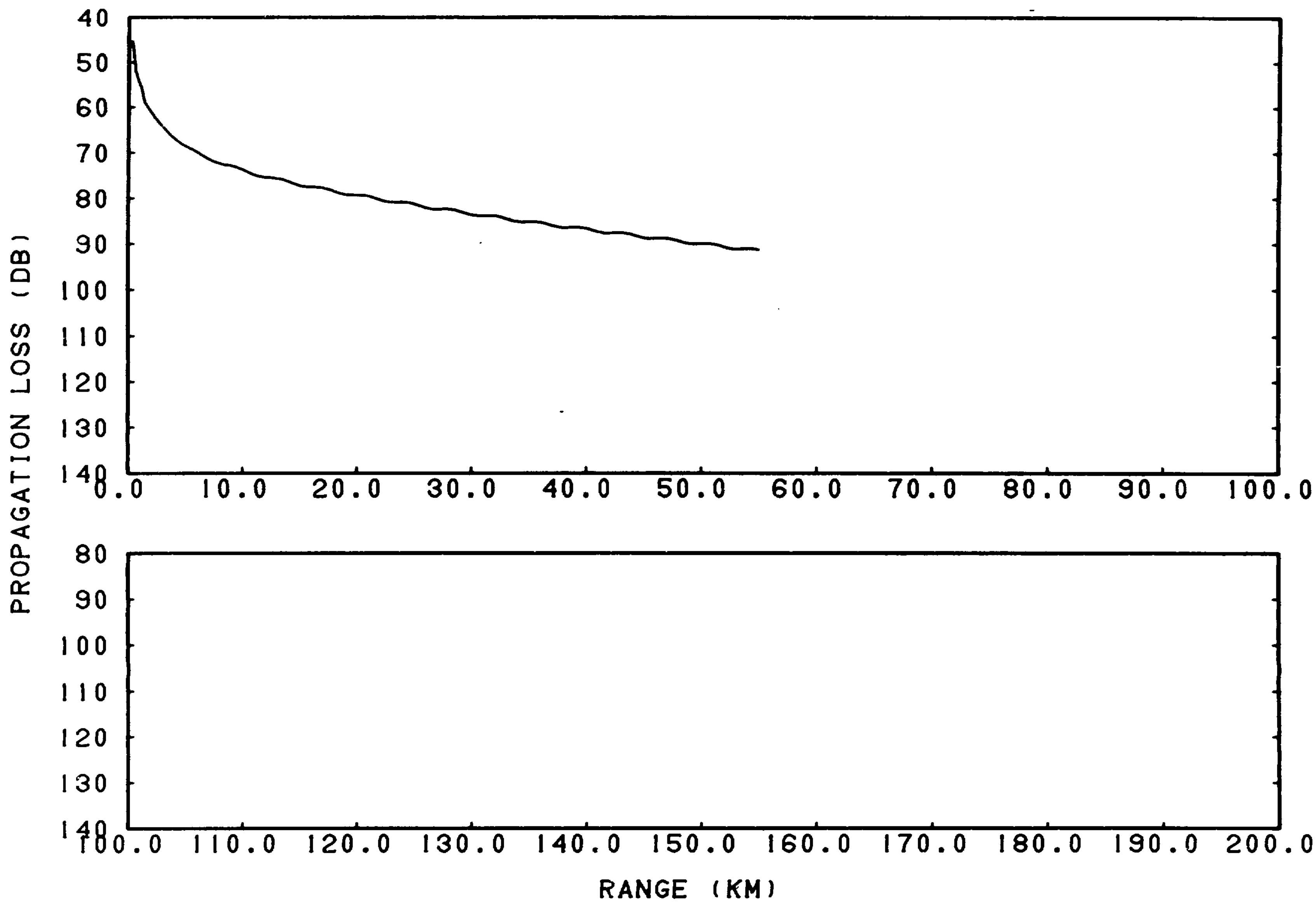
(C) Figure IIIG-37. RAYMODE Coherent, Station THORN, Run 2, Source Depth = 23 Meters, Receiver Depth = 37 Meters, Frequency = 1500 Hertz, Subtracted from Smoothed FASOR, Station THORN, Run 2, Source Depth = 23 Meters, Receiver Depth = 37 Meters, Frequency = 1500 Hertz



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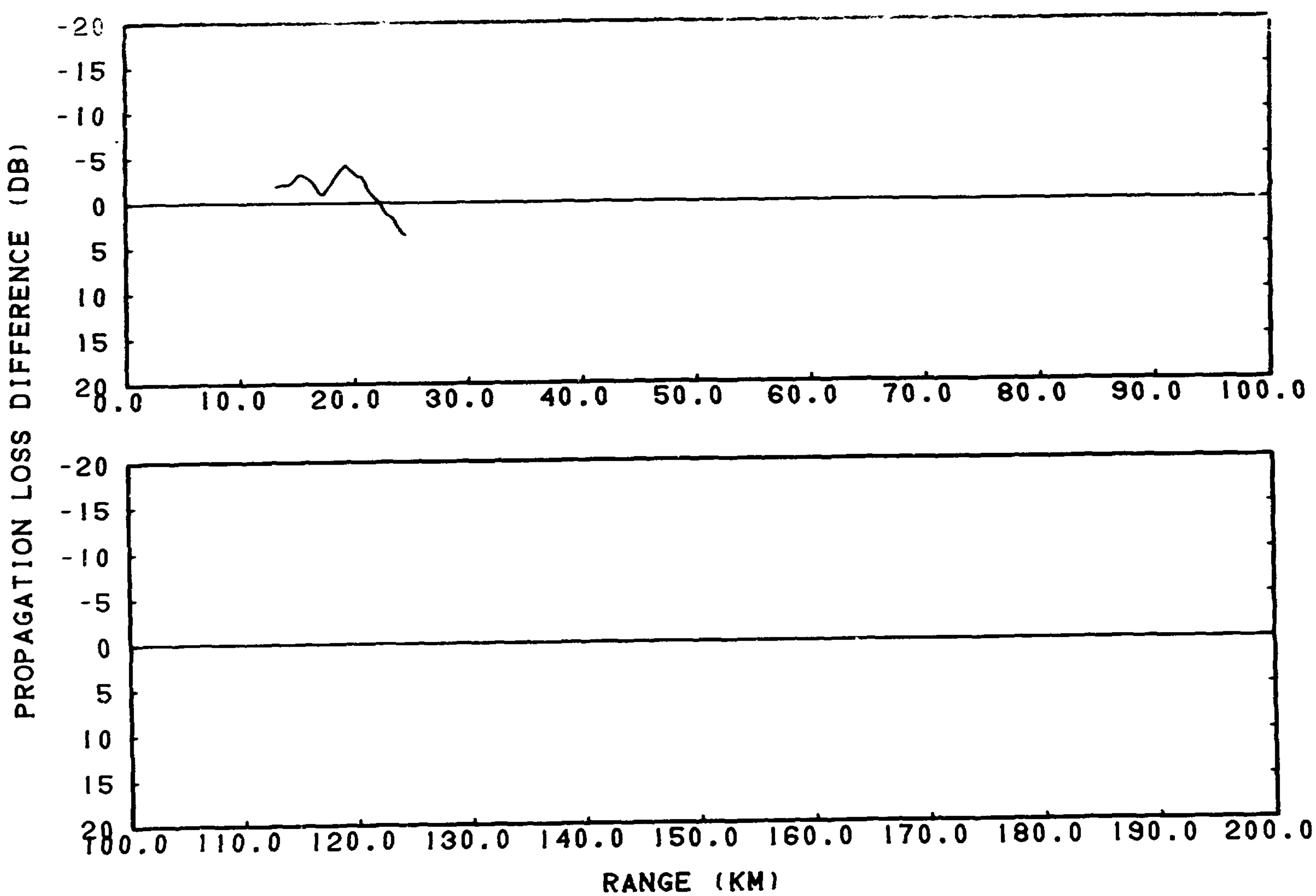
(C) Figure IIIG-38. RAYMODE Incoherent, Station THORN, Run 2, Source Depth = 23 Meters, Receiver Depth = 37 Meters, Frequency = 1500 Hertz



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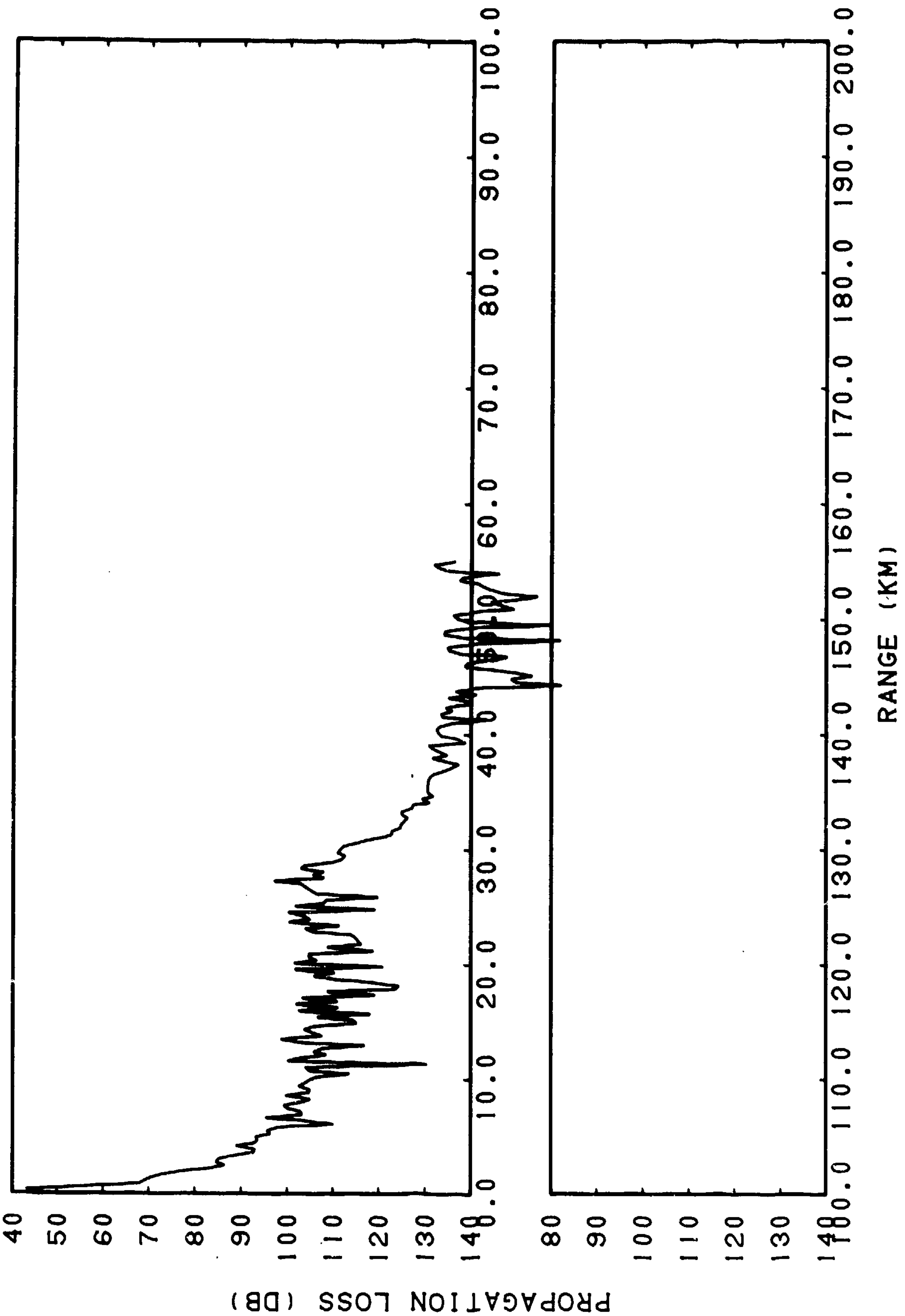
(C) *Figure IIIG-39.* RAYMODE Incoherent, Station THORN, Run 2, Source Depth = 23 Meters, Receiver Depth = 37 Meters Frequency = 1500 Hertz, Subtracted from Smoothed FASOR, Station THORN, Run 2, Source Depth = 23 Meters, Receiver Depth = 37 Meters, Frequency = 1500 Hertz



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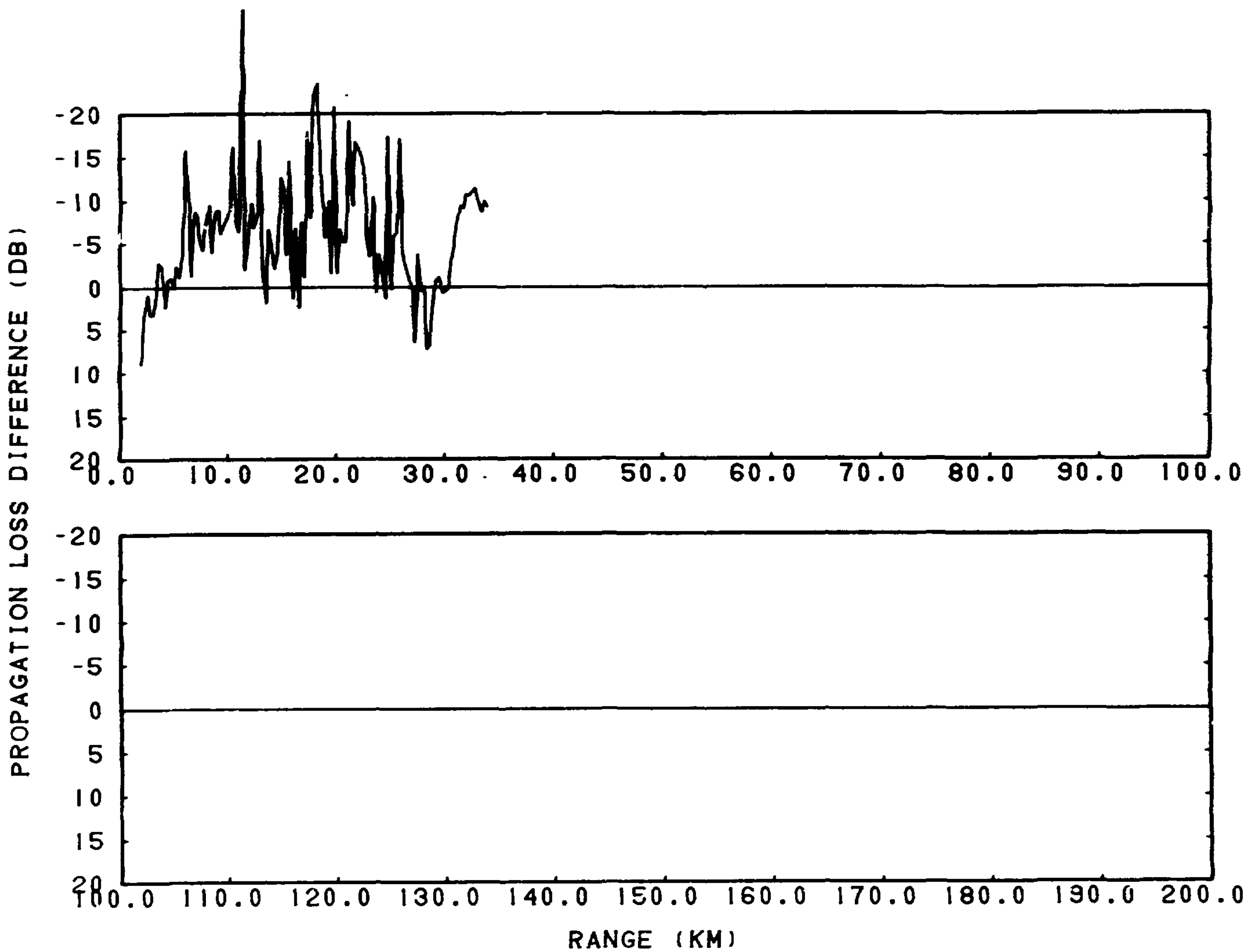
(C) Figure IIIG-40. RAYMODE Coherent, Station REDWOOD, Run 3, Source Depth = 6.1 Meters, Receiver Depth = 37 Meters, Frequency = 1500 Hertz



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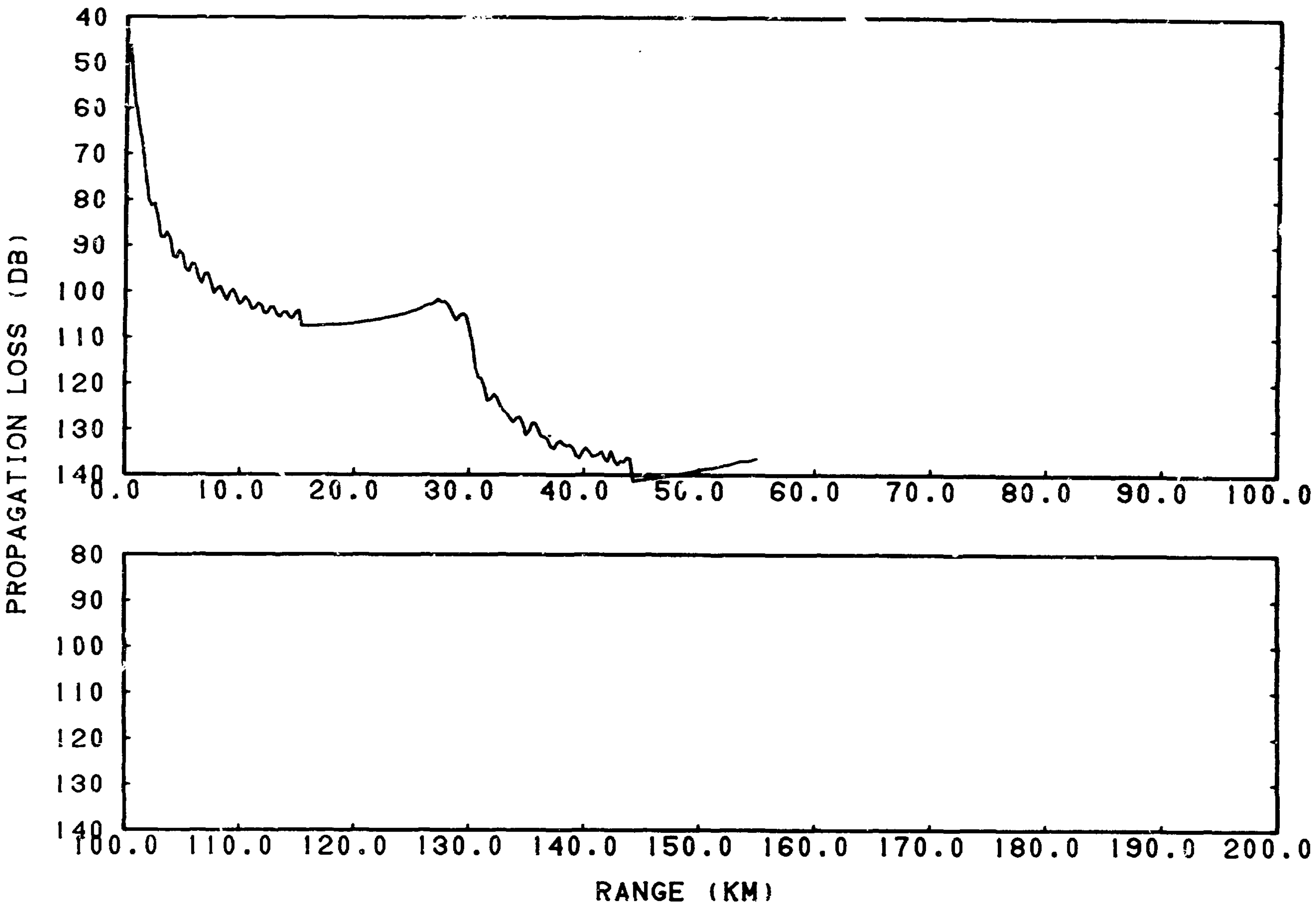
(C) Figure IIIG-41. RAYMODE Coherent, Station REDWOOD, Run 3, Source Depth = 6.1 Meters, Receiver Depth = 37 Meters, Frequency = 1500 Hertz, Subtracted from Smoothed FASOR, Station REDWOOD, Run 3, Source Depth = 6.1 Meters, Receiver Depth = 37 Meters, Frequency = 1500 Hertz



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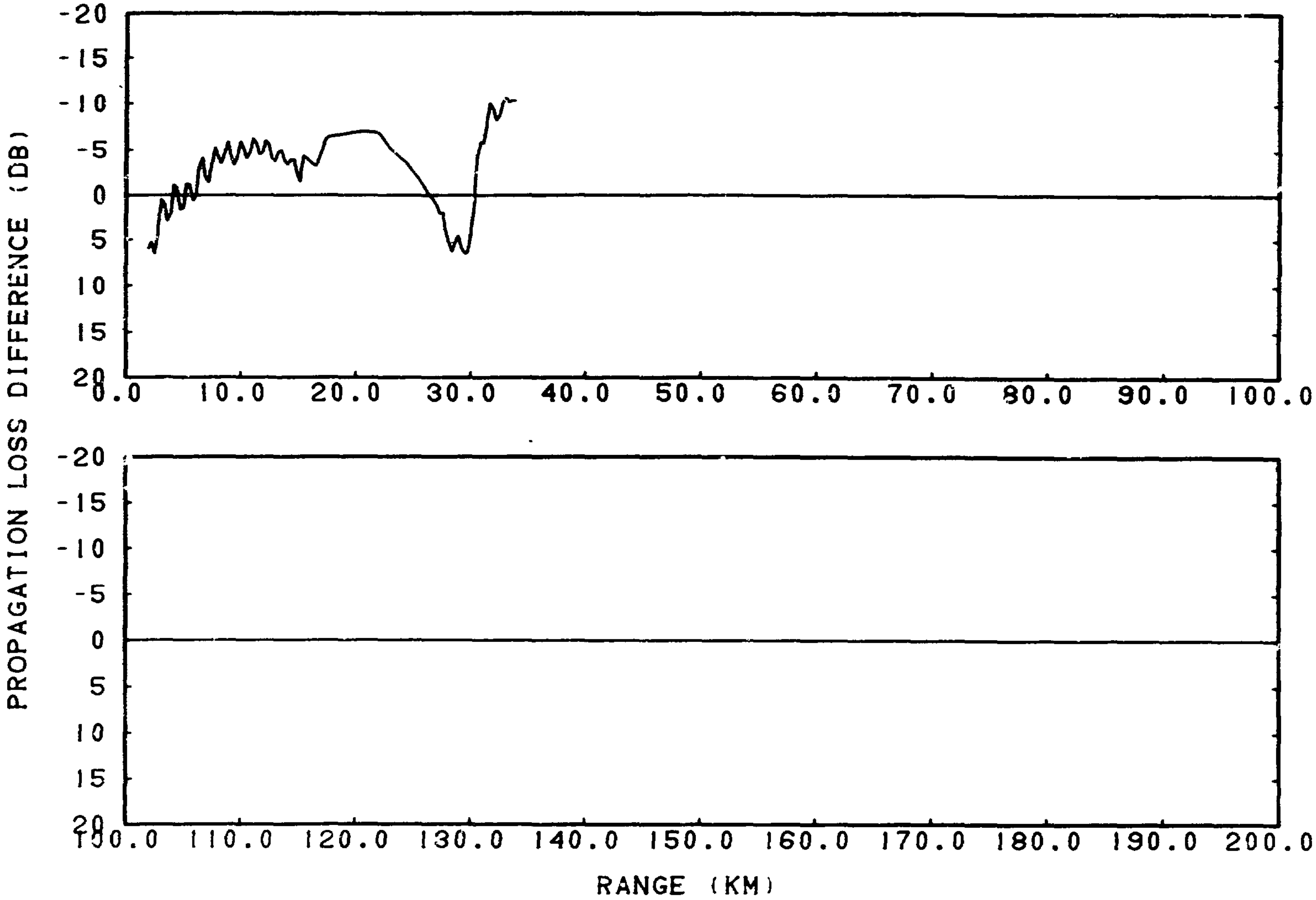
(C) Figure IIIG-42. RAYMODE Incoherent, Station REDWOOD, Run 3, Source Depth = 6.1 Meters, Receiver Depth = 37 Meters, Frequency = 1500 Hertz



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(C) Figure IIIG-43. RAYMODE Incoherent, Station REDWOOD, Run 3, Source Depth = 6.1 Meters, Receiver Depth = 37 Meters, Frequency = 1500 Hertz, Subtracted from Smoothed FASOR, Station REDWOOD Run 3, Source Depth = 6.1 Meters, Receiver Depth = 37 Meters, Frequency = 1500 Hertz

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Appendix IIIH. Accuracy Assessment of RAYMODE X Compared to Gulf of Alaska Experimental Data (U)

Gulf of Alaska (U)

Environment (U)

(C) Seven environments in the Gulf of Alaska (GOA) acoustic experiment were chosen as suitable for the evaluation of range independent propagation loss models. The acoustic measurements in the seven environments are referred to as runs 140, 143, 124, 108, 107, 112B and 112A. The sound speed profiles for these environments are given in Figures IIIH-1 through IIIH-7. All profiles are basically the same, with shallow sound channels the axes of which vary between 75 and 90 meters. Surface sound speeds are between 1476 and 1480 meters per second. Runs 140, 143, 124 and 112B profiles have a surface duct to a depth of 10 meters. Bottom depths vary from 4042 to 4078 meters. Positive depth excess is found to vary between 2850 and 3050 meters. The bottom of the sound channel is between 1000 and 1200 meters (as defined by the reciprocal depth to the surface sound speed or the sound speed at the bottom of the surface duct when one exists).

(C) The bottom loss versus grazing angle curve was the same for all runs and is given in Table IIIH-1. The bottom loss is MGS Type 5 and is independent of frequency above 1000 hertz. The bottom loss is 10.6 dB at 0 degrees, 14.3 dB at 15 degrees and a maximum of 18.2 dB at normal incidence.

Test Cases (U)

(C) There are fourteen test cases for the Gulf of Alaska experiments, corresponding to two receiver depths for each of seven runs:

CASE	RUN NUMBER	SOURCE DEPTH (m)	RECEIVER DEPTH (m)	FREQUENCY (kHz)	MINIMUM RANGE (km)	MAXIMUM RANGE (km)
I	140	30.5	30.5	1.5	37.0	63.0
II	140	30.5	304.8	1.5	37.0	63.0
III	143	30.5	30.5	1.5	8.5	53.0
IV	143	30.5	304.8	1.5	8.5	53.0
V	124	30.5	30.5	1.5	2.5	11.0
VI	124	30.5	304.8	1.5	2.5	11.0
VII	108	1067.0	30.5	2.5	2.5	28.0
VIII	108	1067.0	304.8	2.5	2.5	28.0
IX	108	1067.0	30.5	2.5	30.0	67.0
X	107	1067.0	304.8	2.5	30.0	67.0
XI	112B	304.8	30.5	2.5	2.0	19.5
XII	112B	304.8	304.8	2.5	2.0	19.5
XIII	112A	304.8	30.5	2.5	15.0	58.0
XIV	112A	304.8	304.8	2.5	15.0	58.0

(C) In Cases I, III and V, source and receiver are at the same depth in the upper part of the sound channel. In Cases II, IV and VI, both source and receiver are in the sound channel, but on either side of the axis. In Cases VII through X, the source is below the sound channel and the receiver is in the channel either above the axis at 30.5 m or below the axis at 305 m. For Cases XI through XIV the source is in the lower half of the sound channel and the receiver is either at the same depth of 305 m or above the channel axis at 30.5 m. The dominant propagation is either via the sound channel (purely refracted) paths or half-channel (refracted-surface reflected) paths. Due to the nature of the sound speed profile and relatively high bottom loss (MGS Type 5), bottom reflected energy is not a significant factor.

Accuracy Assessment Results (U)

(C) The accuracy assessment procedures applied to the RAYMODE X outputs and the experimental data are described in section 1.1 of this volume and in greater detail in section 5 of Volume I of this series with the exception that the coherent model output in not smoothed before subtraction from the experimental data. The Gulf of Alaska experimental data (Cases I-XIV) are plotted in Figures IIIH-8 through IIIH-21. This same data, after smoothing by a 0.5 km window running average is shown in Figures IIIH-22 through IIIH-35. The experimental data are characterized by large fluctuations, even after smoothing for Cases I-VI and XIII. When this is combined with the lack of smoothing in the RAYMODE X coherent output before subtraction, the large standard deviations (>5 dB) observed for smoothed GOA data minus RAYMODE X coherent output in Table IIIH-2 are not surprising. The standard deviations for smoothed GOA data minus RAYMODE X incoherent results are generally 2-3 dB less than those for the coherent RAYMODE X results. This is, however, usually offset by an increase in mean differences as first RAYMODE X coherent; and second, RAYMODE X incoherent results are subtracted from GOA smoothed data.

(U) For each case the following figures are produced: (a) the RAYMODE X coherent output, (b) the RAYMODE X coherent result subtracted from Gulf of Alaska data smoothed in 0.5 km increments, (c) RAYMODE X incoherent output, and (d) RAYMODE X incoherent results subtracted from Gulf of Alaska data smoothed in 0.5 km increments. These plots are found in Figures IIIH-36 through IIIH-91 for the fourteen cases.

(C) Means and standard deviations of differences between the smoothed Gulf of Alaska data and the RAYMODE X results (for the coherent and incoherent phase addition options) are given in Table IIIH-2. For Case I, the mean difference of 4.1 dB would be lessened if either GOA data and RAYMODE X coherent results were unsmoothed or if both were smoothed. The high-loss feature in the GOA data of 42 km is not duplicated in either the coherent or incoherent model results. The smoothing of the GOA data was in dB space rather than intensity space; had the smoothing been done in intensity space instead, the smoothed GOA curve would be about 5 dB higher (i.e., toward less loss) for fluctuations of 10-15 dB. This would result in subtraction of 5 dB from all means in Table IIIH-2, yielding overall better agreement. In Case I, fluctuations of GOA data and RAYMODE coherent results are similar over the interval 43 to 48 km. Otherwise, the RAYMODE coherent fluctuations are smaller than GOA's. The RAYMODE incoherent result is a low-loss envelope for the GOA data. For Case II, RAYMODE coherent fluctuations are of the same magnitude as the GOA unsmoothed data. The smoothing of the GOA data improved the mean difference (a +3 dB mean difference would be more reasonable). The high-loss feature centered at 42 km in the GOA data is not observed in either the coherent or incoherent model output. Aside from this high-loss feature, agreement between the incoherent

RAYMODE output and the smoothed GOA data is remarkably close. In Case III, the fine-scale fluctuations in the unsmoothed GOA data are not seen in the RAYMODE coherent result but large-scale fluctuations of the same order of magnitude are seen in both. The large scale fluctuations are out of phase, however, and result in a large standard deviation. The incoherent RAYMODE X result provides a low-loss envelope for the unsmoothed data. For Case IV, the Gulf of Alaska fluctuations are 10-15 dB as compared to 3-10 dB for RAYMODE X coherent output. Had the RAYMODE coherent result been smoothed the standard deviation of 5.7 dB would be less but the mean difference of -1.9 dB would decrease. The RAYMODE X incoherent output is about 5 dB too great to be the low-loss envelope of the GOA unsmoothed data. The match between RAYMODE incoherent and smoothed GOA data is seen to yield a mean difference of 0.7 dB and a standard deviation of 3 dB. For Case V, the RAYMODE X coherent and GOA unsmoothed data are quite similar with respect to their mean values. Fluctuations, however, are as great as 30 dB for the GOA data and as great as 15 dB for RAYMODE X coherent results. RAYMODE incoherent shows different structure than either smoothed or unsmoothed Gulf of Alaska data. For Case VI, the unsmoothed GOA data exhibits fluctuations varying from 3 to 30 dB; the coherent RAYMODE curve shows fluctuations varying from 2 to 15 dB in the data interval (2.5-11 km). Although the curves have a similar appearance, phase differences between peaks and nulls result in a large standard deviation. A displacement of the RAYMODE curve to greater range by 1 km would significantly enhance agreement; this may be merely coincidental. Incoherent RAYMODE output does not show the deep fades of the GOA unsmoothed data and is a low-loss envelope for that data over the first half of the data interval, thereafter showing higher propagation loss than the GOA data. For Case VII, the unsmoothed GOA data and the RAYMODE X coherent output are parallel (in terms of low-loss envelopes) but separated by approximately 10 dB with the model showing less loss. The incoherent RAYMODE result is entirely different from GOA data. To 18 km, the low-loss envelope of the GOA data is 5 dB greater (i.e., has greater propagation loss than the RAYMODE incoherent output. From 18 km to 28 km the disagreement is worse due to the presence of a convergence zone in the RAYMODE incoherent curve, a feature lacking in the GOA data. For Case VIII, the RAYMODE X coherent curve shows 3 dB less propagation loss than the low-loss envelope for the unsmoothed GOA data. Note that these two curves are very nearly parallel. This is also true for RAYMODE X incoherent compared to the unsmoothed GOA low-loss envelope. Here, two low-loss peaks in the RAYMODE curve at 18 and 26 km seem to be duplicated in the GOA data. Peaks in the GOA data at 8 and 15 km are not, however, seen in the incoherent model result. For Case IX, the RAYMODE coherent curve shows less loss and a different slope than unsmoothed GOA data from 30 km to the onset of the convergence zone (CZ) at about 46 km; From this range to the end of the GOA data at 67 km the RAYMODE coherent curve is nearly the low-loss envelope of the GOA data. The fluctuations of the GOA data are 10-15 dB; fluctuations of the RAYMODE coherent output are 3-8 dB. The RAYMODE incoherent curve is almost an exact low-loss envelope for the unsmoothed GOA data from the onset of the CZ to 67 km. Before this the RAYMODE incoherent curve shows less loss (by as much as 8 dB) than the GOA low-loss envelope and has a quite different slope. In Case X, a convergence zone is seen in the GOA data and RAYMODE incoherent but not in RAYMODE coherent (unless the incoherent curve is used as an aid). Nevertheless, when RAYMODE coherent and unsmoothed GOA data are compared, similarity in the CZ region is found. Before the CZ, RAYMODE coherent shows less loss than GOA low-loss envelope and vice versa after the CZ. GOA shows 10 dB fluctuations; RAYMODE coherent shows 2-10 dB fluctuations; The RAYMODE incoherent curve is above the GOA low-loss envelope before the CZ and differs in slope. In the CZ,

RAYMODE incoherent provides a good low-loss GOA data envelope; after the CZ, RAYMODE incoherent has 3 dB less loss than the GOA envelope. In Case XI, from 2 to 12 km the RAYMODE coherent curve and the unsmoothed GOA data envelope are quite similar; from 12 to 19.5 km the RAYMODE curve shows less propagation loss than the GOA low-loss envelope. Fluctuations are about 3 dB for RAYMODE coherent and unsmoothed GOA data; interference features are of similar scale. The RAYMODE incoherent curve is roughly parallel to the GOA envelope but at 3 dB less loss. In Case XII, the fluctuations are of similar scale (5-15 dB) for RAYMODE coherent and unsmoothed GOA data but more rapid for GOA. Basic agreement is not found, however, and some RAYMODE structure from 12 to 17 km is not seen in the GOA data. The high loss dip in the middle of the GOA data is not evident in RAYMODE incoherent. Aside from this, the RAYMODE incoherent curve is the low-loss envelope for GOA data. In Case XIII, the anomalous rise (to lower values) in the Gulf of Alaska propagation loss data is not found in the RAYMODE X coherent or incoherent curves. GOA fluctuations are 10-15 dB compared to RAYMODE coherent's 5-15 dB and are more rapid. After the anomalous section, the RAYMODE coherent and unsmoothed GOA data agree in slope from 27 to 52 km, but RAYMODE has about 3 dB less loss. RAYMODE and GOA basically agree in level from 52 to 58 km. RAYMODE incoherent plus 3 dB is a good low-loss envelope for the GOA data from 27 to 52 km (the 3 dB is not needed from 52 to 58 km). For Case XIV, fluctuations are about 12 dB for unsmoothed GOA data and 5-20 for RAYMODE X coherent. The RAYMODE X coherent curve and the GOA data have similar low-loss envelopes. RAYMODE X incoherent provides an almost perfect envelope for the Gulf of Alaska unsmoothed data.

(C) We now turn to the FOM results. Tables IIIH-3 through IIIH-16 give detection coverage as a function of figure of merit in 5 dB steps for the fourteen cases. In what follows we shall refer to detections per opportunity. This is the same as Zonal Detection Coverage as listed and defined in the tables. For Case I, at FOM = 80 dB, the detection coverage for GOA is slight (2 km), for RAYMODE incoherent there is none, and for RAYMODE coherent detection coverage is over 8 km. At FOM = 85 dB, GOA and RAYMODE give similar coverage in 100% ZDC. For Case XI, at FOM = 75, GOA and RAYMODE coherent have nearly identical coverage and RAYMODE incoherent coverage is twice as long (to 11.5 km). It is not until FOM = 90 dB that the full range extent (to 19.5 km) is covered by GOA data at a ZDC at least 35% at all ranges. At FOM = 85 dB, however, the full range extent is covered by RAYMODE incoherent at 100% ZDC and by RAYMODE coherent with ZDC 75% or greater. For Case XII, at FOM = 70 and 75 dB, RAYMODE coverage is more extensive and at equal or greater ZDC. From FOM > 80 dB, GOA and RAYMODE show detection coverage to the maximum range of 19.5 km, with ZDC at least 65% for RAYMODE coherent, 100% for RAYMODE incoherent and as low as 10% between 7.5 and 16.5 km for GOA. For Case XIII, at FOM = 85 dB, RAYMODE has substantial ZDC over almost the entire interval of 15-58 km whereas GOA has essentially no coverage. At FOM = 90 dB, GOA has detection capability over almost the entire interval but at a low 15% ZDC; this compares to 65% for RAYMODE coherent and 100% for RAYMODE incoherent. At 105 dB, GOA has at least 50% ZDC at all ranges. For Case XIV, at FOM = 80 dB, RAYMODE coherent has detection with 2 to 4 km gaps to 48.5 km at 25% ZDC or greater; RAYMODE incoherent gives detection to 33 km at 60% or greater; GOA gives detection to 33 km at a low 10% ZDC. By FOM = 95 dB, GOA and RAYMODE have total range coverage with at least 50% ZDC.

General Conclusions (U):

(C) Fluctuations were not as rapid for RAYMODE coherent as for GOA data and were larger for GOA by factors as great as two (in dB space) with the exceptions of Case I where fluctuations were 10-15

dB for each, Case XI with 3 dB fluctuations, Cases XII and XIII with 5-15 dB fluctuations, and Case XIV where GOA fluctuations were 12 dB and RAYMODE's varied between 5 and 20 dB. Note: The final four cases are in the sound channel with source below the axis; frequency of 2.5 kHz. (2) The 1.5 kHz results (Cases I-IV) show basic similarity between GOA and RAYMODE coherent results. The RAYMODE incoherent curve usually provided a low-propagation loss envelope for the unsmoothed GOA data. (3) There is good agreement in start and end ranges between GOA and RAYMODE convergence zones except that in Case VII a CZ was predicted by RAYMODE incoherent but not by RAYMODE coherent nor evident in GOA data. (4) Results for the 1067 m source were inconsistent. More often than not, however, RAYMODE results corresponded to low-loss envelopes of GOA data (Case VII showed severe unexplained disagreement). (5) For the last four cases (305 m source), the RAYMODE curves were generally low-loss envelopes for GOA data or parallel to the low-loss envelope but with 3 dB less loss. (6) For the 1.5 kHz data, figure of merit analysis shows the extent of range coverage of GOA data to be greater than or equal to that of RAYMODE output. This trend is reversed for the 2.5 kHz data, for which RAYMODE had consistently better range coverage than did GOA data. (7) Over range increments where both RAYMODE and GOA data had detection coverage, the ZDC (detections per opportunity in percent) was greatest for RAYMODE incoherent (usually 100%) and least for GOA data due to fluctuations. Two exceptions were Case II for which the ZDC's were about equal and Case IV for which the GOA data had better ZDC than either RAYMODE phase option resultant.

(C) Table IIIH-1. Bottom Loss in dB Versus Grazing Angle in Degrees. MGS Type 5. Frequency ≥ 1000 Hertz.

Θ	BL	Θ	BL	Θ	BL
0	10.6	30	15.8	60	17.3
2	11.6	32	15.9	62	17.3
4	12.3	34	16.0	64	17.4
6	12.8	36	16.1	66	17.5
8	13.2	38	16.3	68	17.6
10	13.6	40	16.4	70	17.6
12	13.9	42	16.5	72	17.7
14	14.2	44	16.6	74	17.7
16	14.5	46	16.7	76	17.8
18	14.7	48	16.8	78	17.9
20	14.9	50	16.9	80	17.9
22	15.1	52	16.9	82	18.0
24	15.3	54	17.0	84	18.0
26	15.4	56	17.1	86	18.1
28	15.6	58	17.2	88	18.1

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(C) Table IIIH-2. Means (μ) and Standard Deviations (σ) in dB of Differences Obtained by Subtracting RAYMODE X Model Results from Gulf of Alaska Experimental Data.[1]

Case	Run	Frequency (kHz)	Source Depth (m)	Receiver Depth (m)	RAYMODE X COHERENT μ	RAYMODE X COHERENT σ	RAYMODE X INCOHERENT μ	RAYMODE X INCOHERENT σ
I	140	1.5	30.5	30.5	4.1	6.3	6.2	4.2
II	140	1.5	30.5	30[illegible].8	-0.9	7.0	3.3	4.7
III	143	1.5	30.5	30.5	-1.1	7.3	5.3	4.2
IV	143	1.5	30.5	304.8	-1.9	5.7	0.7	3.0
V	124	1.5	30.5	30.5	2.0	8.1	3.4	5.7
VI	124	1.5	30.5	304.8	-2.8	7.5	3.7	5.8
VII	108	2.5	1067	30.5	13.4	5.4	14.9	4.1
VIII	108	2.5	1067	304.8	8.9	5.1	11.4	2.9
IX	107	2.5	1067	30.5	8.0	6.0	9.7	3.4
X	107	2.5	1067	304.8	3.8	6.8	6.3	3.2
XI	112B	2.5	304.8	30.5	7.3	6.3	10.7	2.1
XII	112B	2.5	304.8	304.8	4.4	7.4	8.7	2.4
XIII	112A	2.5	304.8	30.5	10.8	8.8	14.0	6.7
XIV	112A	2.5	304.8	304.8	6.2	7.2	7.6	2.7

[1] Gulf of Alaska data were smoothed by application of a running average with a 2-kilometer window.

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(C) Table IIIH-3. Detection Range in km as a Function of Figure of Merit (FOM) in dB for Gulf of Alaska, Run 140 (37-63 km) Experimental Data and RAYMODE X Model Results.
Case I.
(Source Depth = 30.5 m, Receive Depth = 30.5 m, Frequency = 1.5 kHz)

Data Set	FOM	R_c[2]	Range > R_c
Gulf of Alaska	80		ZDC[2] 50%, 38-40 km
RAYMODE X Coherent	80		ZDC 15%, 39-47 km
RAYMODE X Incoherent	80		
Gulf of Alaska	85		ZDC 30%, 37-41 km ZDC 15%, 44.5-61 km
RAYMODE X Coherent	85		ZDC 50%, 37-57 km
RAYMODE X Incoherent	85		100% coverage 37-50.5 km ZDC 25%, 51.5 - 60.5 km
Gulf of Alaska	90		ZDC 80%, 37-41 km ZDC 50%, 43-63 km
RAYMODE X Coherent	90		100% coverage 37-43 km ZDC 70%, 43.5-66.5 km
RAYMODE X Incoherent	90		100% coverage 37-57.5 km, and 58-62 km, and 62.5-63 km
Gulf of Alaska	95		ZDC 95%, 37-40 km; ZDC 20%, 40-50 km; ZDC 85%, 50-63 km
RAYMODE X Coherent	95		100% coverage 37-43 km; ZDC 85%, 43-48 km; 100% coverage 48.5-63 km except dropouts at 52.5 km, 62 km and 62.5 km
RAYMODE X Incoherent	95		100% coverage 37-63 km
Gulf of Alaska	100	40.5	ZDC 50%, 40.5-50 km ZDC 95%, 50-63 km
RAYMODE X Coherent	100		100% coverage 37-63 km except dropout at 48 km, 62 km and 62.5 km
RAYMODE X Incoherent	100	>63.0	
Gulf of Alaska	105	42.0	ZDC 80%, 42-43.5 km 98% coverage past 43.5 km
RAYMODE X Coherent	105		100% coverage 37-63 km
RAYMODE X Incoherent	105	>63.0	

1. R_c = Range to which detection coverage is continuous.

2. ZDC = Zonal Detection Coverage in percentage of the indicated range over which detection is possible.

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(C) Table IIIH-4. **Detection Range in km as a Function of Figure of Merit (FOM) in dB for Gulf of Alaska, Run 140 (37-63 km) Experimental Data and RAYMODE X Model Results. Case II. (Source Depth = 30.5 m, Receiver Depth = 305 m, Frequency = 1.5 kHz)**

Data Set	FOM	R_c [1]	Range > R_c
Gulf of Alaska	80		100%, coverage, 38-40 km ZDC[2] 20%, 46-54.5 km
RAYMODE X Coherent	80		Peaks at 37 km, 37.5 km, 38-38.5 km, 40 km and 43.5 km
RAYMODE X Incoherent	80		100% coverage, 38-39.5 km
Gulf of Alaska	85		ZDC 60%, 37-40 km; ZDC 10%, 40-45 km; ZDC 50%, 45-63 km
RAYMODE X Coherent	85		ZDC 40%, 37-43.5 km, ZDC 1[illegible], 47-59 km
RAYMODE X Incoherent	85	47.0	ZDC 35%, 53-58 km Peaks at 47.5 km, 48 km
Gulf of Alaska	90		ZDC 95%, 37-40 km; ZDC 20%, 40-44 km ZDC 70%, 44-63 km
RAYMODE X Coherent	90		100% coverage 37-40 km ZDC 60%, 40-63 km
RAYMODE X Incoherent	90	60.0	100% coverage, 60.5-62.5 km; peak at 63 km
Gulf of Alaska	95		100% coverage, 37-40 km; ZDC 60%, 40-44 km 100% coverage, 44-52.5 km; ZDC 85%, 52.5-63 km
RAYMODE X Coherent	95	41.5	ZDC 75%, 41.5-63 km
RAYMODE X Incoherent	95	>63.0	
Gulf of Alaska	100		100% coverage, 37-40km; ZDC 85%, 40-44 km; ZDC 95%, 44-63 km
RAYMODE X Coherent	100	55.0	100% coverage to 63 km except dropouts at 55 km, 57.5 km, 58 km
RAYMODE X Incoherent	100	>63.0	

1. R_c = Range to which detection coverage is continuous.
2. ZDC = Zonal Detection Coverage in percentage of the indicated range over which detection is possible.

(C) Table IIIH-5. Detection Range in km as a Function of Figure of Merit (FOM) in dB for Gulf of Alaska, Run 143 (8.5-53.0 km) Experimental Data and RAYMODE X Model Results. Case III. (Source Depth = 30.5 m, Reciever Depth = 30.5 m, Frequency = 1.5 kHz)

Data Set	FOM	R_c [1]	Range > R_c
Gulf of Alaska	80		ZDC[2] 25%, 10.5-30 km
RAYMODE X Coherent	80		
RAYMODE X Incoherent	80		100% coverage 20.5-26.5 km
Gulf of Alaska	85		ZDC 50%, 10-38 km ZDC 20%, 41.5-52 km
RAYMODE X Coherent	85		100% coverage 10.5-12.5 km, 26.5-31 km, and 36-42 km
RAYMODE X Incoherent	85		100% coverage 8.5-32.5 km, 33-48 km except for dropouts at 35.5 km and 38.5 km
Gulf of Alaska	90		ZDC 30%, 10-13 km; ZDC 30%, 13-30.5 km ZDC 40%, 30.5-53 km
RAYMODE X Coherent	90		100% coverage 8.5-16 km, 19.5-21 km, 22-23 km, 24-32.5 km, 35.5-45.5 km
RAYMODE X Incoherent	90	>53.0	
Gulf of Alaska	95		ZDC 40%, 9-13 km; ZDC 90%, 13-30.5 km ZDC 60%, 30.5-53 km
RAYMODE X Coherent	95		100% coverage 8.5-17.5 km, 18.5-33.5 km, 35-50 km 51-53 km and peak at 50.5 km
RAYMODE X Incoherent	95	>53.0	
Gulf of Alaska	100		ZDC 70%, 9-13 km; ZDC 90%, 9-38 km ZDC 80%, 38-53 km
RAYMODE X Coherent	100	34.5	100% coverage 35-53 km
RAYMODE X Incoherent	100	>53.0	

1. R_c = Range to which detection coverage is continuous.

2. ZDC = Zonal Detection Coverage in percentage of the indicated range over which detection is possible.

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(C) Table IIIH-6. Detection Range in km as a Function of Figure of Merit (FOM) in dB for Gulf of Alaska, Run 143 (8.5-53.0 km) Experimental Data and RAYMODE X Model Results. Case IV. (Source Depth = 30.5 m, Receiver Depth = 305 m, Frequency = 1.5 kHz)

Data Set	FOM	R_c [1]	Range > R_c
Gulf of Alaska	80		ZDC 40%, 9.5-35 km; ZDC 15%, 35-53 km
RAYMODE X Coherent	80		ZDC 10%, 9-42 km
RAYMODE X Incoherent	80	8.5	100% coverage 17-19.5 km, 20-20.5 km, 35-37 km
Gulf of Alaska	85		ZDC 90%, 9-29.5 km; ZDC 40%, 29.5-53 km
RAYMODE X Coherent	85		ZDC 60%, 8.5-42 km, peaks at 46.5 km and 47.5 km
RAYMODE X Incoherent	85	35.0	100% coverage 35-43 km, 43.5-44 km, 47-48.5 km
Gulf of Alaska	90		ZDC 90%, 8.5-30 km; ZDC 60%, 30-53 km
RAYMODE X Coherent	90		ZDC 80%, 8.5-53 km
RAYMODE X Incoherent	90	>53	
Gulf of Alaska	95		ZDC 98%, 8.5-30 km; ZDC 95%, 30-53 km
RAYMODE X Coherent	95	12.5	100% coverage to 53 km except dropouts at 12.5 km, 21 km, 27 km, 32.5 km, 42 km, 48 km, 49 km
RAYMODE X Incoherent	95	>53.0	
Gulf of Alaska	100		ZDC 98%, 8.5-53 km
RAYMODE X Coherent	100	27.0	100% coverage to 53 km except dropouts at 27 km, 33 km
RAYMODE X Incoherent	100	>53	

1. R_c = Range to which detection coverage is continuous.

2. ZDC = Zonal Detection Coverage in percentage of the indicated range over which detection is possible.

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(C) Table IIIH-7. Detection Range in km as a Function of Figure of Merit (FOM) in dB for Gulf of Alaska, Run 124 (2.5-11.0 km) Experimental Data and RAYMODE X Model Results. Case V. (Source Depth = 30.5 m, Receiver Depth = 30.5 m, Frequency = 1.5 kHz)

Data Set	FOM	R_c [1]	Range > R_c
Gulf of Alaska	75		ZDC[2] 65%, 4-6 km
RAYMODE X Coherent	75		ZDC 10%, 4.5-11 km
RAYMODE X Incoherent	75		
Gulf of Alaska	80		ZDC 60%, 3.5-11 km
RAYMODE X Coherent	80		ZDC 45%, 4.5-11 km
RAYMODE X Incoherent	80		100% coverage 4.5 to > 11 km
Gulf of Alaska	85		ZDC 70%, 3.5-11 km
RAYMODE X Coherent	85		ZDC 60%, 4.0-11 km
RAYMODE X Incoherent	85	2.5	100% coverage 4.5 to > 11 km
Gulf of Alaska	90		ZDC 80%, 2.5-11 km
RAYMODE X Coherent	90		100% coverage 3-4 km, 4.5 - > 11 km
RAYMODE X Incoherent	90	>11.0	
Gulf of Alaska	95		ZDC 85%, 2.5-11 km
RAYMODE X Coherent	95	>11.0	
RAYMODE X Incoherent	95	>11.0	

1. R_c = Range to which detection coverage is continuous.

2. ZDC = Zonal Detection Coverage in percentage of the indicated range over which detection is possible.

(C) Table IIIH-8. Detection Range in km as a Function of Figure of Merit (FOM) in dB for Gulf of Alaska, Run 124 (2.5-11.0 km) Experimental Data and RAYMODE X Model Results. Case VI. (Source Depth = 30.5 m, Receiver Depth = 305 m, Frequency = 1.5 kHz)

Data Set	FOM	R_c[1]	Range > R_c
Gulf of Alaska	75		ZDC[2] 50%, 2.5-11 km
RAYMODE X Coherent	75		100% coverage 2.5-4 km, 4.5-5.5 km, and 5.5-6.5 km
RAYMODE X Incoherent	75	6.5	100% coverage 10-11 km
Gulf of Alaska	80		ZDC 75%, 2.5-11 km
RAYMODE X Coherent	80		100% coverage 2.5-4 km, 4.5-6.5 km; ZDC 35%, 7-11 km
RAYMODE X Incoherent	80	>11.0	
Gulf of Alaska	85		ZDC 60%, 2.5-6 km 100% coverage past 6 km
RAYMODE X Coherent	85	4.0	100% coverage 4.5-7 km, 7.5-8.5 km, and 9 to > 11 km
RAYMODE X Incoherent	85	>11.0	
Gulf of Alaska	90		ZDC 70%, 2.5-6 km 100% coverage past 6 km
RAYMODE X Coherent	90	4.0	100% coverage to 11 km except dropouts at 7 and 8.5 km
RAYMODE X Incoherent	90	>11.0	
Gulf of Alaska	95		ZDC 85%, 2.5-6 km 100% coverage past 6 km
RAYMODE X Coherent	95	>11.0	
RAYMODE X Incoherent	95	>11.0	

1. R_c = Range to which detection coverage is continuous.

2. ZDC = Zonal Detection Coverage in percentage of the indicated range over which detection is possible.

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(C) Table IIIH-9. Detection Range in km as a Function of Figure of Merit (FOM) in dB for Gulf of Alaska, Run 108 (2.5-28.0 km) Experimental Data and RAYMODE X Model Results. Case VII. (Source Depth = 1067 m, Receiver Depth = 30.5 m, Frequency = 2.5 kHz)

Data Set	FOM	R_c [1]	Range > R_c
Gulf of Alaska	75		
RAYMODE X Coherent	75		ZDC[2] 80%, 2.5-4.5 km
RAYMODE X Incoherent	75	4.5	
Gulf of Alaska	80		Single peak at 2.5 km
RAYMODE X Coherent	80	3.5	ZDC 40%, 3.5-11.5 km; ZDC 10%, 17-28 km
RAYMODE X Incoherent	80	7.0	100% coverage 16.5-18 km, .5-26 km, and a peak at 18.5 km
Gulf of Alaska	85		Single peaks at 2.5 and 8.5 km
RAYMODE X Coherent	85	5.0	ZDC 55%, 5.0-28 km
RAYMODE X Incoherent	85	>28.0	
Gulf of Alaska	90		ZDC 20%, 2.5-20 km; 100% coverage 27.5-28 km
RAYMODE X Coherent	90	13.5	100% coverage 14-19.5 km except for dropouts at 16 km and 18 km; 100% coverage 20-26 km, 27-28 km
RAYMODE X Incoherent	90	>28.0	
Gulf of Alaska	95		ZDC 40%, 2.5-28 km
RAYMODE X Coherent	95	14.0	100% coverage to 28 km except for dropouts at 14 and 19.5 km
RAYMODE X Incoherent	95	>28.0	
Gulf of Alaska	100		ZDC 60%, 2.5-28 km
RAYMODE X Coherent	100	>28.0	
RAYMODE X Incoherent	100	>28.0	

1. R_c = Range to which detection coverage is continuous.

2. ZDC = Zonal Detection Coverage in percentage of the indicated range over which detection is possible.

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(C) Table IIIH-10. Detection Range in km as a Function of Figure of Merit (FOM) in dB for Gulf of Alaska, Run 108 (2.5-28.0 km) Experimental Data and RAYMODE X Model Results. Case VIII. (Source Depth = 1067 m, Receiver Depth = 30.5 m, Frequency = 2.5 kHz)

Data Set	FOM	R_c[1]	Range > R_c
Gulf of Alaska	80		100% coverage, 2.5-3.5 km
RAYMODE X Coherent	80		Peak at 2.5 km; ZDC[2] 40%, 4.5-16.5 km 100% coverage 20.5-21 km and 21-22.5 km and -28 km
RAYMODE X Incoherent	80		100% coverage 4.5-7.5 km and 20-24.5 km
Gulf of Alaska	85		ZDC 10%, 2.5-20 km Single peak at 25 km
RAYMODE X Coherent	85	2.5	100% coverage 2.5-3.5 km and 26.5-28 km ZDC 75%, 4.5-25 km
RAYMODE X Incoherent	85	3.0	100% coverage 4.0-28 km
Gulf of Alaska	90		ZDC 70%, 2.5-9 km; ZDC 50%, 9-20.5 km ZDC 15%, 23-28 km
RAYMODE X Coherent	90	3.5	100% coverage to 25 km except for dropouts at 3.5 km, 6.5 km, 9.5 km, 13 km; coverage 25.5-28 km
RAYMODE X Incoherent	90	4.0	100% coverage 4.5-28 km
Gulf of Alaska	95		ZDC 95%, 2.5-9 km; ZDC 75%, 9-20.5 km ZDC 15%, 23-28 km
RAYMODE X Coherent	95	25.0	100% coverage 25.5-28 km
RAYMODE X Incoherent	95	>28.0	
Gulf of Alaska	100		ZDC 98%, 2.5-20 km; ZDC 90%, 20-28 km
RAYMODE X Coherent	100	25.0	100% coverage to 28 km with dropout at 25 km
RAYMODE X Incoherent	100	>28.0	

1. R_c = Range to which detection coverage is continuous.
2. ZDC = Zonal Detection Coverage in percentage of the indicated range over which detection is possible.

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(C) Table IIIH-11. Detection Range in km as a Function of Figure of Merit (FOM) in dB for Gulf of Alaska, Run 107 (30-67 km) Experimental Data and RAYMODE X Model Results. Case IX. (Source Depth = 1067 m, Receiver Depth = 30.5 m, Frequency = 2.5 kHz)

Data Set	FOM	R_c [1]	CZ Start	CZ End	
Gulf of Alaska	85				
RAYMODE X Coherent	85		46.0	48.0	ZDC[2] 10%, 30-37.5 km
RAYMODE X Incoherent	85		46.0	48.0	
Gulf of Alaska	90		45.0	48.5	Convergence zone detection coverage is 50%
RAYMODE X Coherent	90		45.0	51.0	Convergence zone detection coverage is 60%; ZDC 55%, 30-40.5 km
RAYMODE X Incoherent	90	38.5	45.0	49.0	
Gulf of Alaska	95		45.0	56.0	
RAYMODE X Coherent	95		45.0	53.5	ZDC 80%, 30.0-43.5 km; CZ detection coverage is 85%; ZDC 20%, 54.5-60.5 km
RAYMODE X Incoherent	95	57.0			
Gulf of Alaska	100				ZDC 30%, 30-45 km; ZDC 75%, 45-56 km ZDC 15%, 56-67 km
RAYMODE X Coherent	100		43.0	53.5	100% coverage 30-43 km ZDC 80%, 53.5-67 km
RAYMODE X Incoherent	100	66.0			
Gulf of Alaska	105				ZDC 70%, 30-45 km; ZDC 85%, 45-57 km; ZDC 35%, 57-67 km
RAYMODE X Coherent	105	51.0			100% coverage 52-64 km, and 65-67 km
RAYMODE X Incoherent	105	>67.			
Gulf of Alaska	110				ZDC 85%, 30-45 km; ZDC 95%, 45-57 km ZDC 60%, 57-67 km
RAYMODE X Coherent	110	51.0			100% coverage to 67 km except for dropouts at 51 km and 64 km
RAYMODE X Incoherent	110	>67.0			

1. R_c = Range to which detection coverage is continuous.

2. ZDC = Zonal Detection Coverage in percentage of the indicated range over which detection is possible.

(C) Table IIIH-12. Detection Range in km as a Function of Figure of Merit (FOM) in dB for Gulf of Alaska, Run 107 (30-67 km) Experimental Data and RAYMODE X Model Results.
Case X.
(Source Depth = 1067 m, Receiver Depth = 305 m, Frequency = 2.5 kHz)

Data Set	FOM	R_c [1]	CZ Start	CZ End	
Gulf of Alaska	90		44.0	52.5	Convergence zone detection coverage is 20%
RAYMODE X Coherent	90		43.5	50.5	ZDC[2] 65%, 30-40.5 km Convergence zone detection coverage is 45%
RAYMODE X Incoherent	90	37.5	43.0	50.5	Convergence zone detection coverage is 50%
Gulf of Alaska	95				ZDC 10%, 30-44.5 km; ZDC 40%, 44.5-54.5 km ZDC 5%, 54.5-67 km
RAYMODE X Coherent	95		42.5		ZDC 70%, 30-41.5 km; 60% ZDC 42.5-62.5 km
RAYMODE X Incoherent	95	51.5			100% coverage 52-54 km and 55-56 km
Gulf of Alaska	100				ZDC 50%, 30-44.5 km; ZDC 85%, 44.5-54.5 km ZDC 30%, 54.5-67 km
RAYMODE X Coherent	100		42.5		ZDC 85%, 30-42 km; ZDC 70%, 42.5-67 km
RAYMODE X Incoherent	100	65.0			
Gulf of Alaska	105				ZDC 95%, 30-44.5 km; ZDC 98%, 44.5-54.5 km ZDC 70%, 54.5-67 km
RAYMODE X Coherent	105	35.0			Coverage to 56.5 km except dropouts at 31.5 km, 36 km, 40 km, 51 km; ZDC 85% 57-67 km
RAYMODE X Incoherent	105	>67.0			
Gulf of Alaska	110				100% coverage, 30-55.5 km ZDC 95%, 55.5-67 km
RAYMODE X Coherent	110	35.5			Coverage to 59 km with dropout at 35.5 km 100% coverage 59.5-67 km
RAYMODE X Incoherent	110	>67.0			

1. R_c = Range to which detection coverage is continuous.

2. ZDC = Zonal Detection Coverage in percentage of the indicated range over which detection is possible.

(C) Table IIIH-13. Detection Range in km as a Function of Figure of Merit (FOM) in dB for Gulf of Alaska, Run 112B (2-19.5 km) Experimental Data and RAYMODE X Model Results. Case XI. (Source Depth = 305 m, Receiver Depth = 30.5 m, Frequency = 2.5 kHz)

Data Set	FOM	R_c[1]	Range > R_c
Gulf of Alaska	75		ZDC[2] 50%, 2-6 km
RAYMODE X Coherent	75	5.5	Peaks at 14 km and 16 km
RAYMODE X Incoherent	75	11.5	
Gulf of Alaska	80		ZDC 70%, 2-7 km
RAYMODE X Coherent	80	5.5	ZDC 45%, 6.0-18.5 km
RAYMODE X Incoherent	80	15.0	
Gulf of Alaska	85		ZDC 90%, 2-6.5 km; ZDC 30%, 6.5-11 km ZDC 5%, 11-19.5 km
RAYMODE X Coherent	85	8.5	ZDC 75%, 9.0-19.0 km
RAYMODE X Incoherent	85	>19.5	
Gulf of Alaska	90		ZDC 98%, 2-6 km; ZDC 60%, 6.5-11 km ZDC 35%, 11-19.5 km
RAYMODE X Coherent	90	11.5	ZDC 85%, 12.0-19.5 km
RAYMODE X Incoherent	90	>19.5	
Gulf of Alaska	95	6.5	ZDC 90%, 6.5-11 km; ZDC 60%, 11-19.5 km
RAYMODE X Coherent	95	12.0	Continuous coverage to 19.5 km except for dropouts at 12 km, 13.5 km, and 18.5 km
RAYMODE X Incoherent	95	>19.5	
Gulf of Alaska	100	7.0	ZDC 90%, 7-19.5 km
RAYMODE X Coherent	100	12.0	Continuous coverage to 19.5 km except for dropouts at 12 km and 13.5 km
RAYMODE X Incoherent	100	>19.5	

1. R_c = Range to which detection coverage is continuous.

2. ZDC = Zonal Detection Coverage in percentage of the indicated range over which detection is possible.

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(C) Table IIIH-14. Detection Range in km as a Function of Figure of Merit (FOM) in dB for Gulf of Alaska, Run 112B (2-19.5 km) Experimental Data and RAYMODE X Model Results. Case XII. (Source Depth = 305 m, Receiver Depth = 305 m, Frequency = 2.5 kHz)

Data Set	FOM	R_c [1]	Range > R_c
Gulf of Alaska	70		ZDC[2] 30%, 2-3 km
RAYMODE X Coherent	70	2.5	ZDC 10%, 3-8 km; peak at 11.5 km
RAYMODE X Incoherent	70	5.0	Peak at 6.5 km
Gulf of Alaska	75	2.0	ZDC 30%, 2-7 km
RAYMODE X Coherent	75	3.0	ZDC 35%, 3-11.5 km; 100% coverage 15-16 km and 16.5-18 km
RAYMODE X Incoherent	75	8.5	ZDC 65%, 8.5-12.5 km; ZDC 60%, 15-19 km
Gulf of Alaska	80	3.0	ZDC 85%, 2-7.5 km; ZDC 10%, 7.5-15.5 km ZDC 40%, 15.5-19.5 km
RAYMODE X Coherent	80	3.5	ZDC 65%, 3.5-12.5 km; 100% coverage 14.5-18 km and 18.5-19.5 km
RAYMODE X Incoherent	80	18.5	Continuous coverage to 19.5 km with dropout at 18.5 km
Gulf of Alaska	85	5.5	ZDC 40%, 5.5-19.5 km
RAYMODE X Coherent	85	3.5	ZDC 90%, 3.5-13 km; 100% coverage 14-19.5 km except for dropout at 18 km
RAYMODE X Incoherent	85	>19.5	
Gulf of Alaska	90	6.5	ZDC 6.5%, 6.5-19.5 km
RAYMODE X Coherent	90	3.5	ZDC 98%, 3.5-13.5 km; 100% coverage 14.5-19.5 km except for dropout at 18 km
RAYMODE X Incoherent	90	>19.5	
Gulf of Alaska	95	9.5	ZDC 90%, 10-14 km 100% coverage, 14-19.5 km
RAYMODE X Coherent	95	13.5	100% coverage 14-19.5 km
RAYMODE X Incoherent	95	>19.5	

1. R_c = Range to which detection coverage is continuous.
2. ZDC = Zonal Detection Coverage in percentage of the indicated range over which detection is possible.

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(C) Table IIIH-15. Detection Range in km as a Function of Figure of Merit (FOM) in dB for Gulf of Alaska, Run 112A (15-58 km) Experimental Data and RAYMODE X Model Results. Case XIII. (Source Depth = 305 m, Receiver Depth = 30.5 m, Frequency = 2.5 kHz)

Data Set	FOM	R_c [1]	Range > R_c
Gulf of Alaska	85		ZDC[2] 5%, 30-32 km
RAYMODE X Coherent	85		ZDC 45%, 15-51 km
RAYMODE X Incoherent	85	30.0	ZDC 65%, 30-38 km; ZDC 75%, 44.5-49.0 km
Gulf of Alaska	90		ZDC 15%, 22.5-55 km
RAYMODE X Coherent	90		ZDC 65%, 15-55.5 km
RAYMODE X Incoherent	90	52.5	100% coverage 53-53.5 km and 54-54.5 km
Gulf of Alaska	95		ZDC 50%, 22.5-58 km
RAYMODE X Coherent	95	19.0	100% coverage 19-22 km, 22 km - 34.5 km ZDC 75%, 34.5-58 km
RAYMODE X Incoherent	95	>58	
Gulf of Alaska	100		ZDC 15%, 15-22 km; ZDC 70%, 22-58 km
RAYMODE X Coherent	100	37.0	ZDC 90%, 37-58 km
RAYMODE X Incoherent	100	>58	
Gulf of Alaska	105		ZDC 50%, 15-24 km; ZDC 95%, 24-58 km
RAYMODE X Coherent	105	37.0	ZDC 95%, 37-58 km
RAYMODE X Incoherent	105	>58	
Gulf of Alaska	110		ZDC 80%, 15-24 km; ZDC 98%, 24-58 km
RAYMODE X Coherent	110	>58	
RAYMODE X Incoherent	110	>58	

1. R_c = Range to which detection coverage is continuous.

2. ZDC = Zonal Detection Coverage in percentage of the indicated range over which detection is possible.

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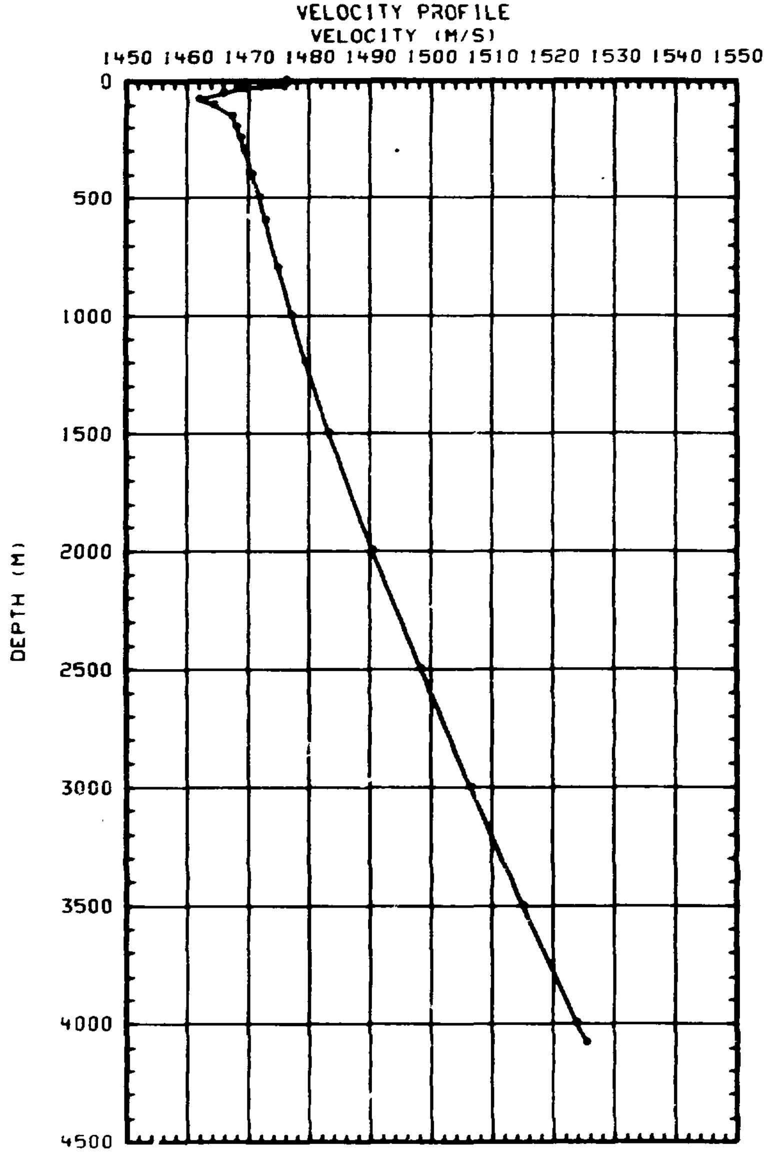
(C) Table IIIH-16. Detection Range in km as a Function of Figure of Merit (FOM) in dB for Gulf of Alaska, Run 112A (15-58 km) Experimental Data and RAYMODE X Model Results. Case XIV. (Source Depth = 305 m, Receiver Depth = 305 m, Frequency = 2.5 kHz)

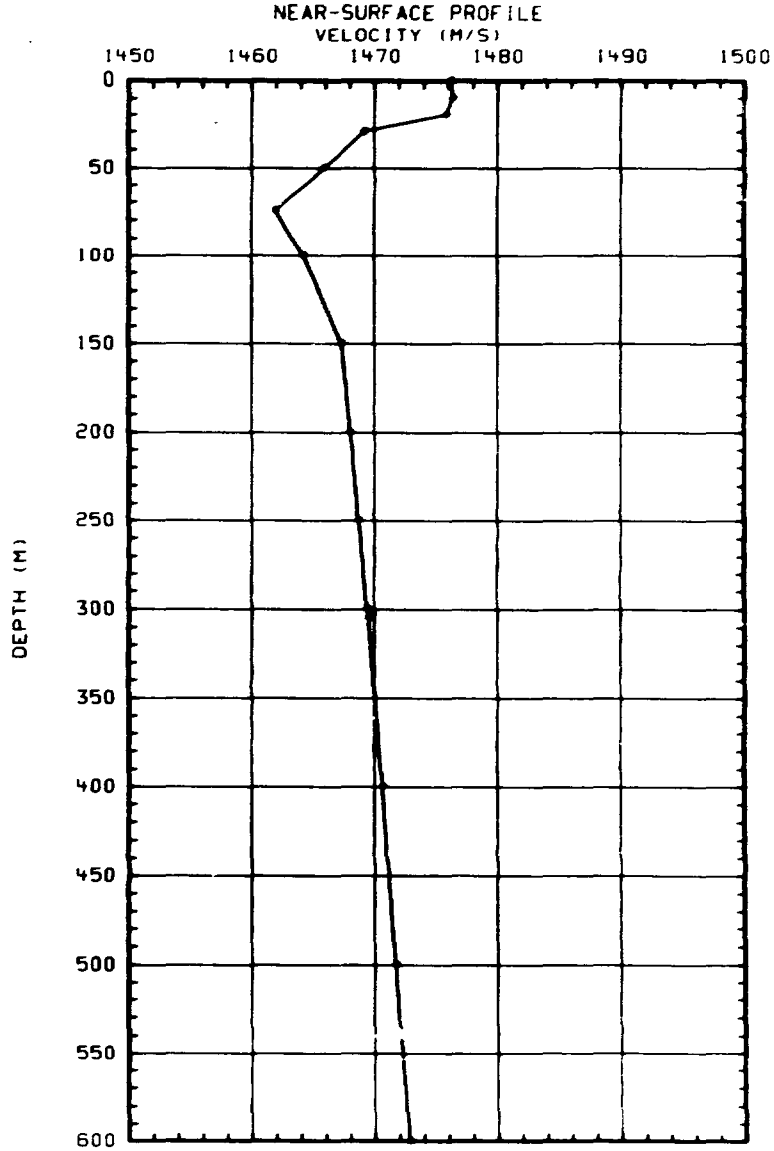
Data Set	FOM	R_c[1]	Range > R_c
Gulf of Alaska	80		ZDC[2] 10%, 15-33 km
RAYMODE X Coherent	80		100% coverage 15-19.5 km; ZDC 45%, 20-28 km; ZDC 35%, 30.5-38.5 km; ZDC 25%, 42-48.5 km
RAYMODE X Incoherent	80	21.0	ZDC 60%, 20-33 km Peaks at 22.5 km and 47 km
Gulf of Alaska	85		ZDC 40%, 15-33 km; ZDC 10%, 33-45 km
RAYMODE X Coherent	85		100% coverage 15-21.5 km; ZDC 45%, 22-52 km Peak at 52.5 km
RAYMODE X Incoherent	85	26.5	100% coverage to 39 km except for dropouts at 26.5 km, 33 km, 37.5 km; ZDC 60%, 39.5-53.0 km
Gulf of Alaska	90		ZDC 80%, 25-33 km; ZDC 40%, 33-47 km ZDC 20%, 47-58 km
RAYMODE X Coherent	90		100% coverage 15-22 km; ZDC 80%, 23-58 km
RAYMODE X Incoherent	90	52.5	ZDC 50%, 52.5-58 km
Gulf of Alaska	95		ZDC 95%, 15-33 km; ZDC 80%, 33-47 km ZDC 50%, 47-58 km
RAYMODE X Coherent	95	22.0	ZDC 95%, 22-45 km ZDC 85%, 45.5-58 km
RAYMODE X Incoherent	95	>58	
Gulf of Alaska	100		ZDC 98%, 15-33 km; ZDC 95%, 33-47 km ZDC 85%, 47-58 km
RAYMODE X Coherent	100	25.0	100% coverage to 58 km except for dropouts at 25 km, 45 km, 46 km, 51 km, 54.5 km
RAYMODE X Incoherent	100	>58	
Gulf of Alaska	105		100% coverage 15-40 km ZDC 90%, 40-58 km
RAYMODE X Coherent	105	25.0	100% coverage to 58 km except for dropouts at 25 km, 45 km, 46 km, 54.5 km
RAYMODE X Incoherent	105	>58	

1. R_c = Range to which detection coverage is continuous.

2. ZDC = Zonal Detection Coverage in percentage of the indicated range over which detection is possible.



DEPTH	VELOCITY
0.0	1476.20
10.0	1476.30
20.0	1475.80
30.0	1469.20
30.5	1469.12
50.0	1465.90
75.0	1461.90
100.0	1464.20
150.0	1467.30
200.0	1468.00
250.0	1468.70
300.0	1469.40
305.0	1469.46
400.0	1470.60
500.0	1471.70
600.0	1472.80
800.0	1474.90
1000.0	1477.10
1200.0	1479.40
1500.0	1483.20
2000.0	1490.40
2500.0	1498.30
3000.0	1506.40
3500.0	1515.00
4000.0	1523.90
4078.0	1525.40



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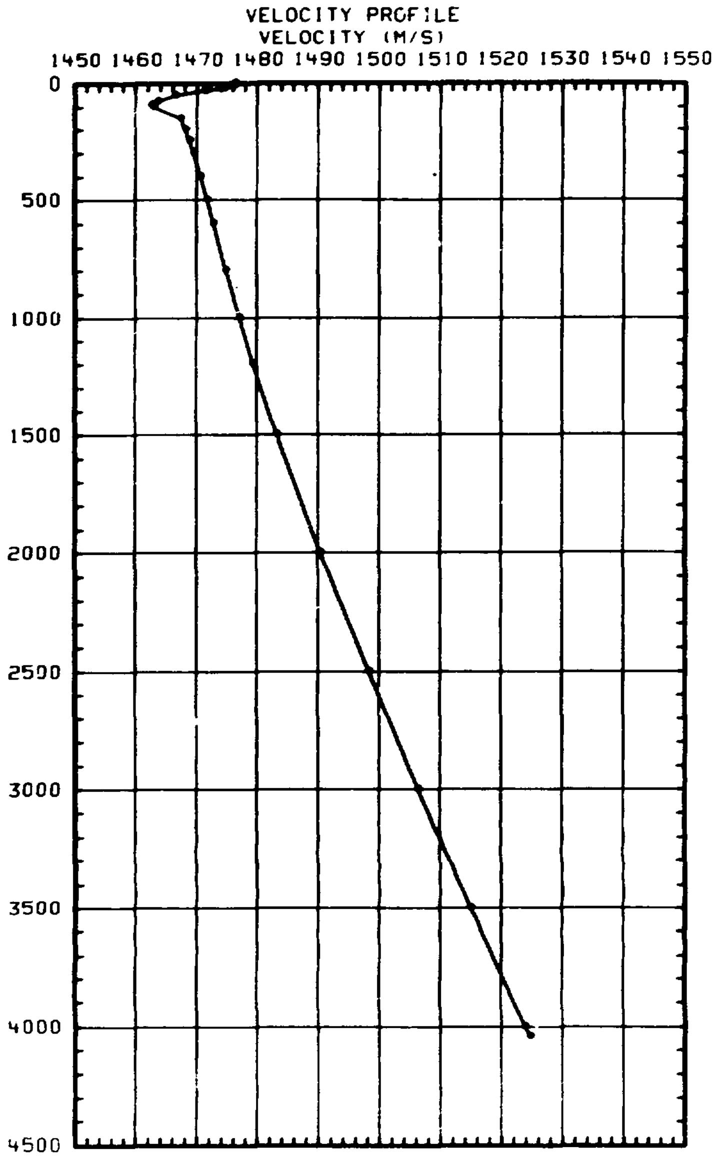
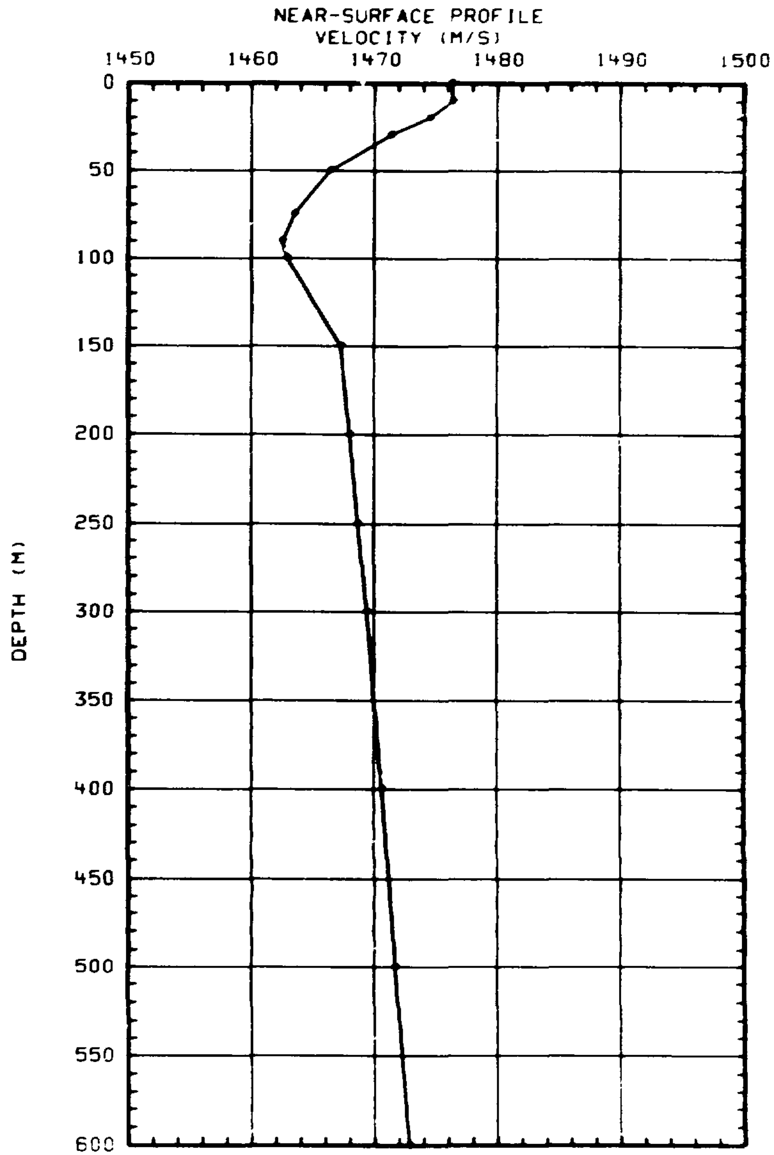
(U) Figure IIIH-1. Gulf of Alaska Run 140 Sound Speed Profile



DEPTH	VELOCITY
0.0	1476.30
10.0	1476.31
20.0	1474.50
30.0	1471.40
30.5	1471.27
50.0	1466.40
75.0	1463.50
90.0	1462.50
100.0	1462.90
150.0	1467.30
200.0	1468.00
250.0	1468.70
300.0	1469.40
400.0	1470.60
500.0	1471.70
500.0	1472.80
800.0	1474.90
1000.0	1477.10
1200.0	1479.40
1500.0	1483.20
2000.0	1490.40
2500.0	1498.30
3000.0	1506.40
3500.0	1515.00
4000.0	1523.90
4042.0	1524.70



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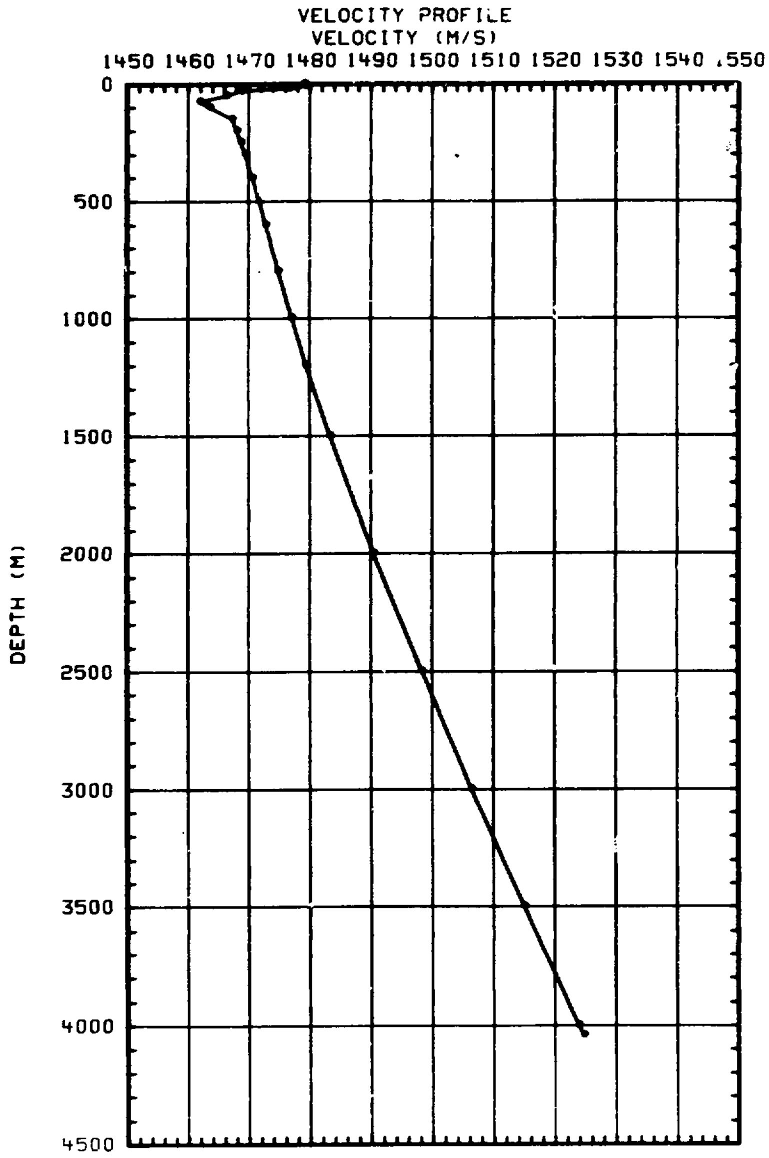
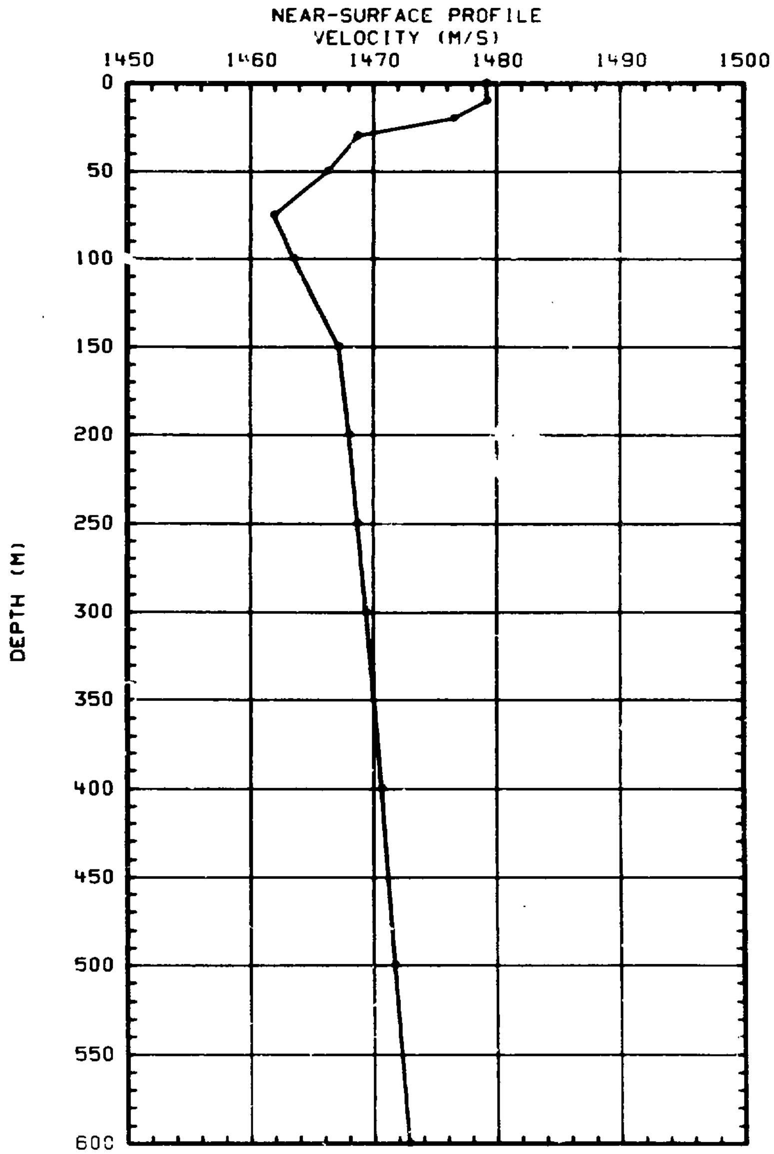
(U) Figure IIIH-2. Gulf of Alaska Run 143 Sound Speed Profile



DEPTH	VELOCITY
0.0	1479.10
10.0	1479.20
20.0	1476.50
30.0	1468.70
30.5	1468.64
50.0	1466.30
75.0	1461.90
100.0	1463.50
150.0	1467.20
200.0	1468.00
250.0	1468.70
300.0	1469.40
400.0	1470.60
500.0	1471.70
600.0	1472.80
800.0	1474.90
1000.0	1477.10
1200.0	1479.40
1500.0	1483.20
2000.0	1490.40
2500.0	1498.30
3000.0	1506.40
3500.0	1515.00
4000.0	1523.90
4042.0	1524.70



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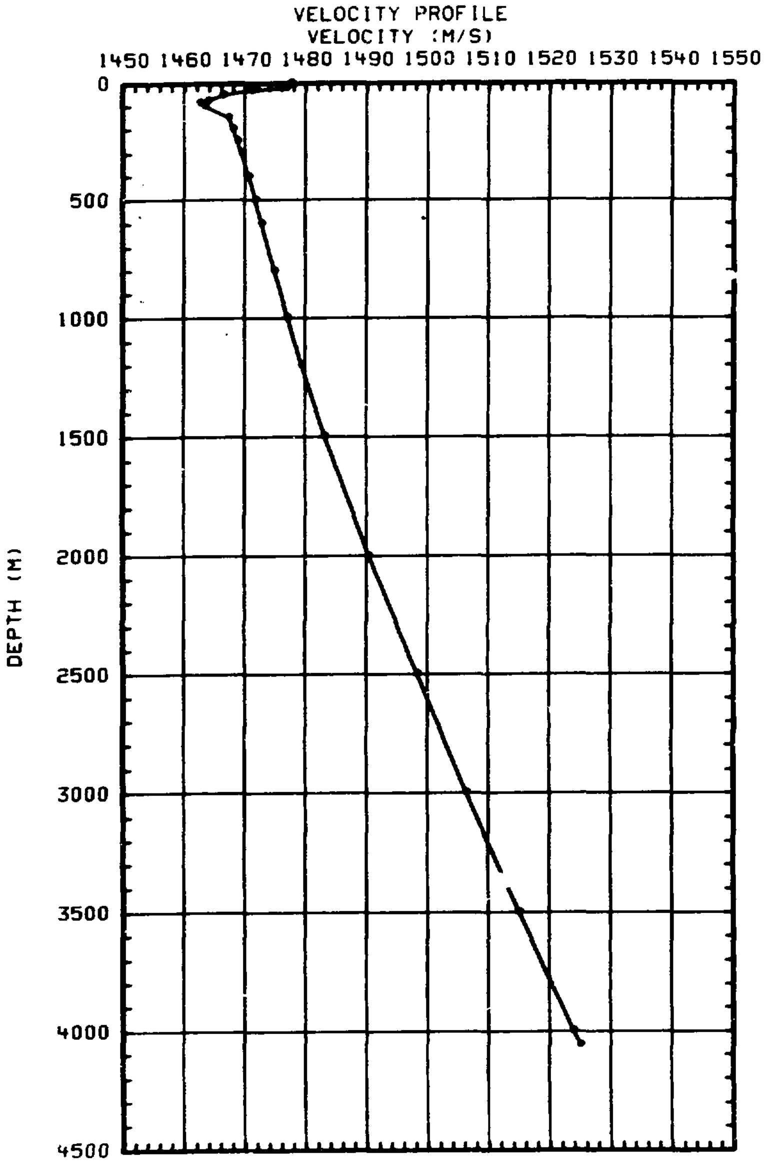
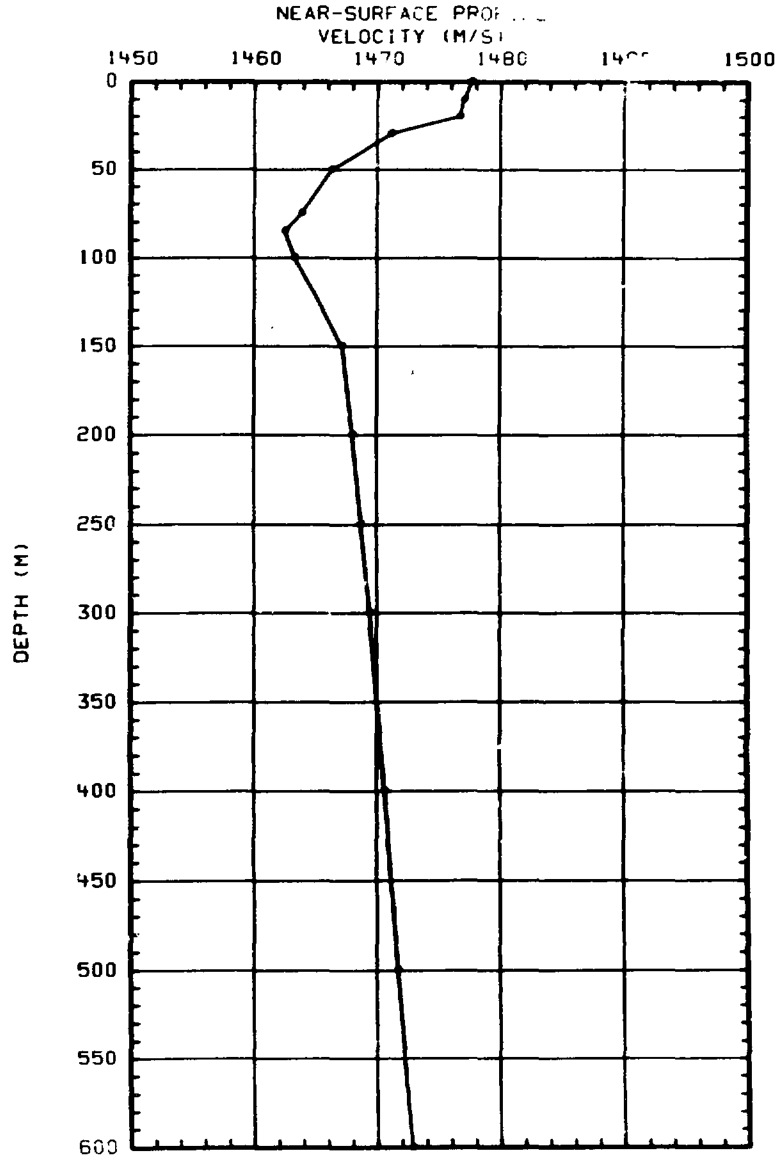
(U) Figure IIIH-3. Gulf of Alaska Run 124 Sound Speed Profile



DEPTH	VELOCITY
0.0	1477.60
10.0	1477.00
20.0	1476.70
30.0	1471.20
30.5	1471.08
50.0	1466.30
75.0	1463.90
85.0	1462.50
100.0	1463.30
150.0	1467.20
200.0	1468.00
250.0	1468.70
300.0	1469.40
400.0	1470.60
500.0	1471.70
600.0	1472.80
800.0	1474.90
1000.0	1477.10
1200.0	1479.40
1500.0	1483.20
2000.0	1490.40
2500.0	1498.30
3000.0	1506.40
3500.0	1515.00
4000.0	1523.90
4060.0	1525.00



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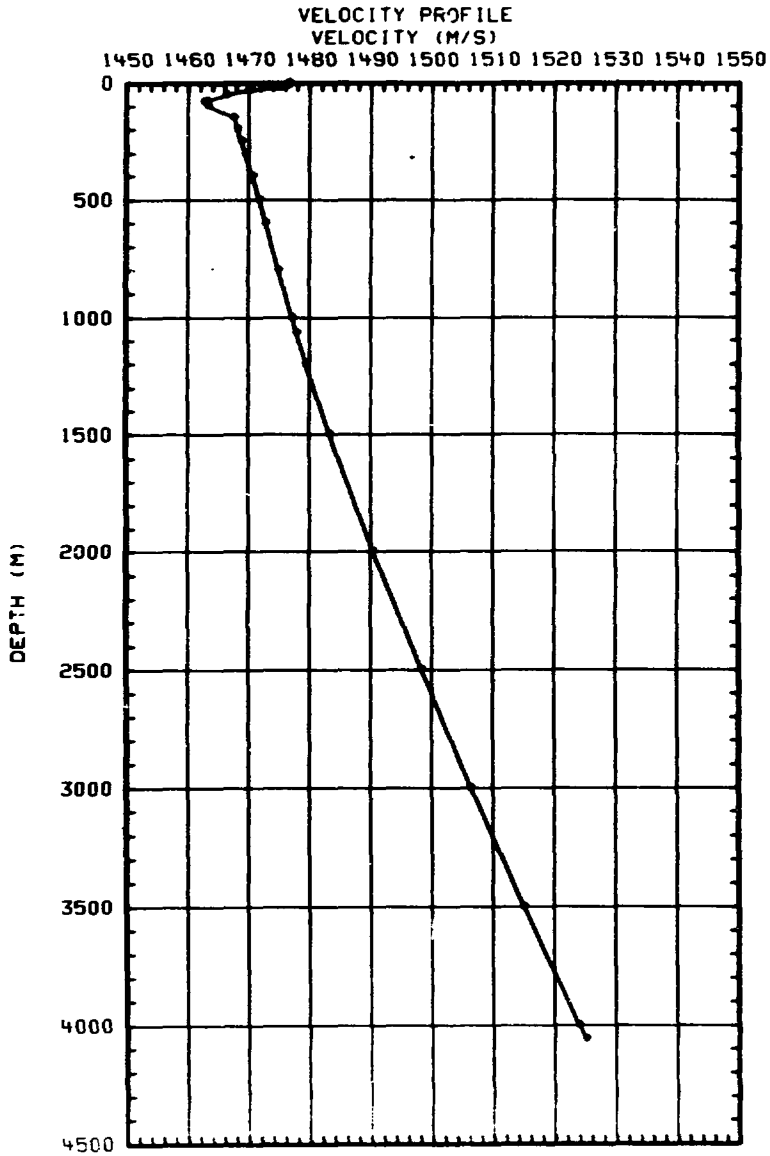
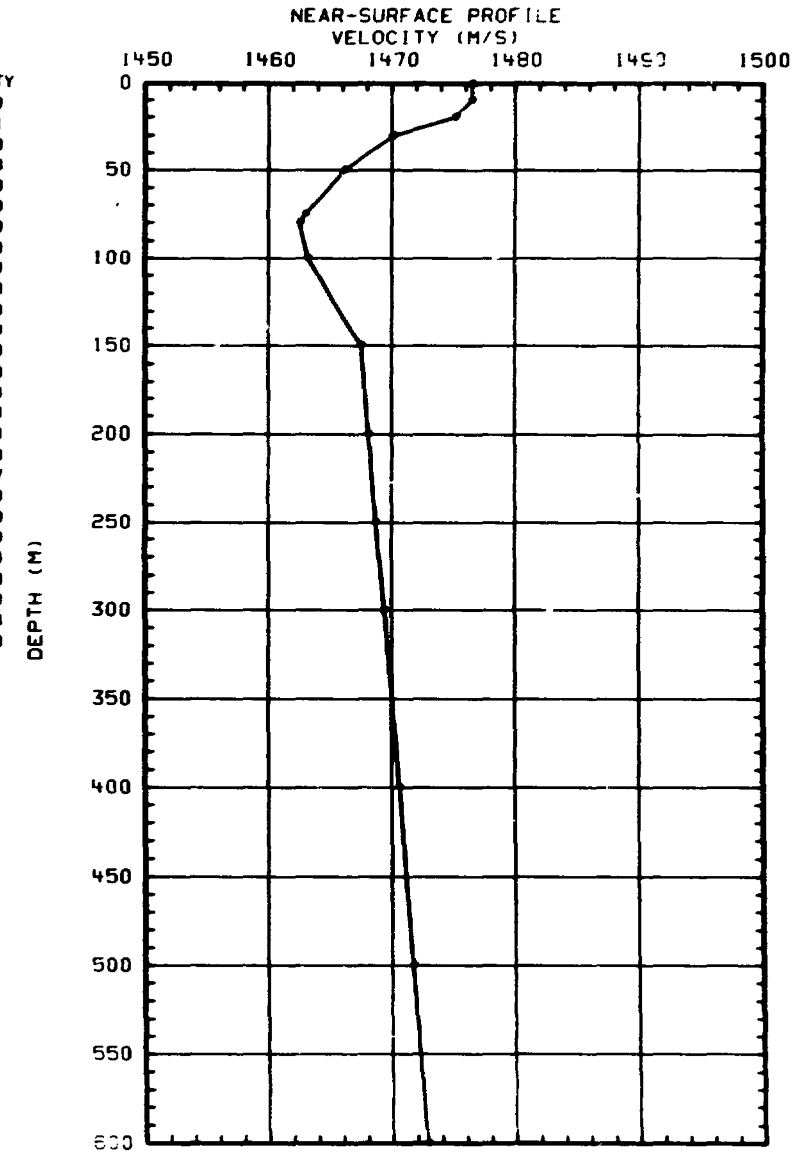
(U) Figure IIIH-4. Gulf of Alaska Run 108 Sound Speed Profile



DEPTH	VELOCITY
0.0	1476.50
10.0	1476.51
20.0	1475.10
30.0	1470.10
30.5	1470.00
50.0	1466.20
75.0	1463.00
80.0	1462.50
100.0	1463.20
150.0	1467.50
200.0	1468.10
250.0	1468.70
300.0	1469.40
400.0	1470.60
500.0	1471.70
600.0	1472.80
800.0	1474.90
1000.0	1477.10
1067.0	1477.87
1200.0	1479.40
1500.0	1483.20
2000.0	1490.40
2500.0	1498.30
3000.0	1506.40
3500.0	1515.00
4000.0	1523.90
4060.0	1525.00



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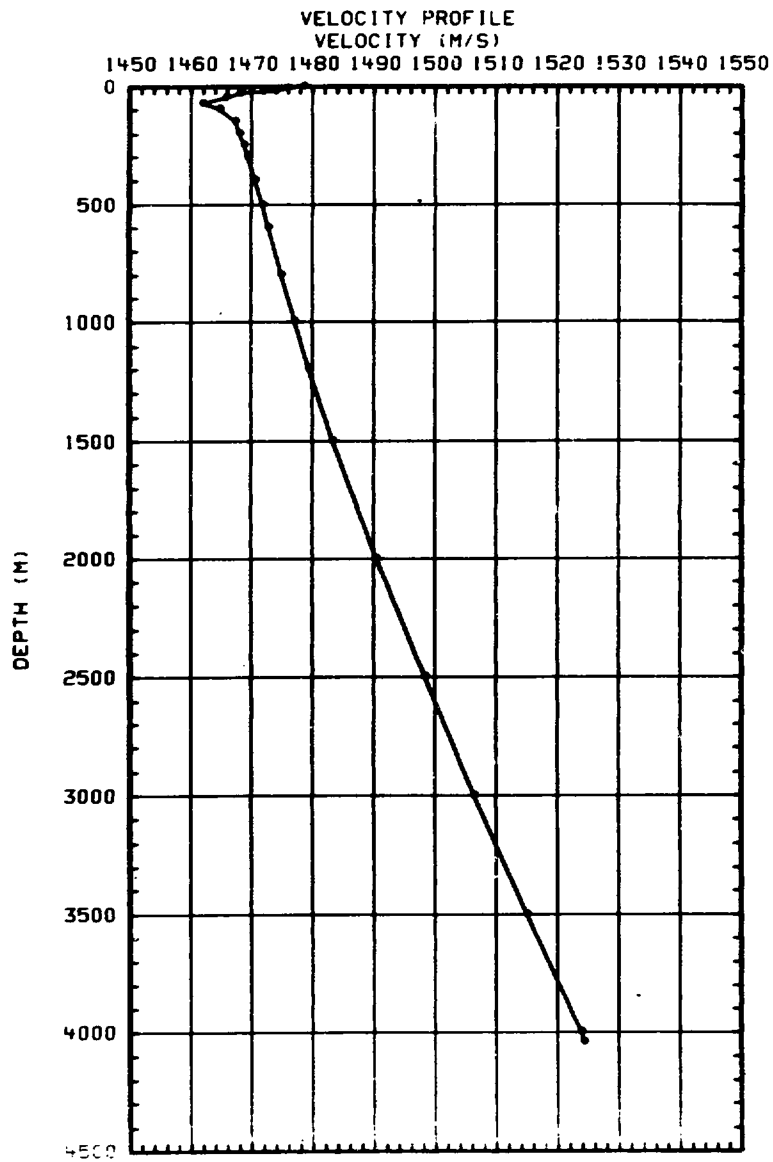
(U) Figure IIIH-5. Gulf of Alaska Run 107 Sound Speed Profile



DEPTH	VELOCITY
0.0	1478.50
10.0	1475.90
20.0	1474.00
30.0	1468.20
30.5	1468.14
50.0	1465.80
75.0	1461.90
100.0	1464.70
150.0	1467.30
200.0	1468.00
250.0	1468.70
300.0	1469.40
305.0	1469.46
400.0	1470.60
500.0	1471.70
600.0	1472.80
800.0	1474.90
1000.0	1477.10
1200.0	1479.40
1500.0	1483.20
2000.0	1490.40
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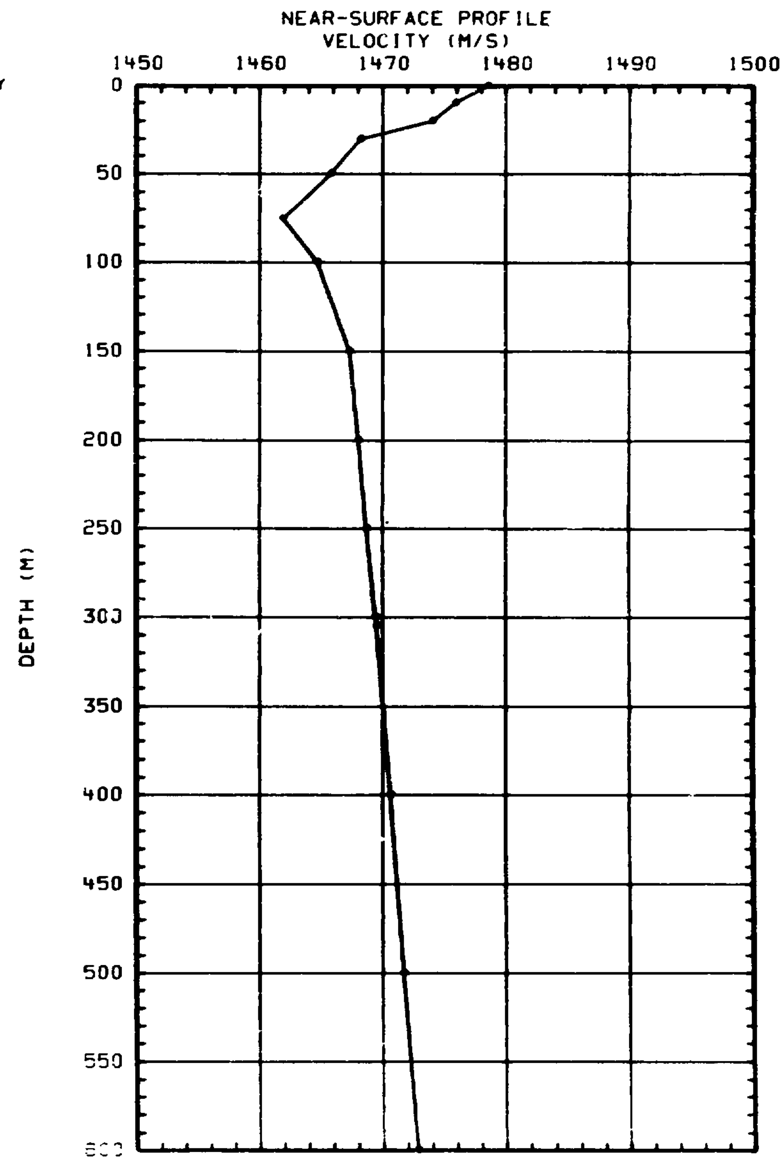
3000.0	1506.40
3500.0	1515.00
4000.0	1523.90
4042.0	1524.33



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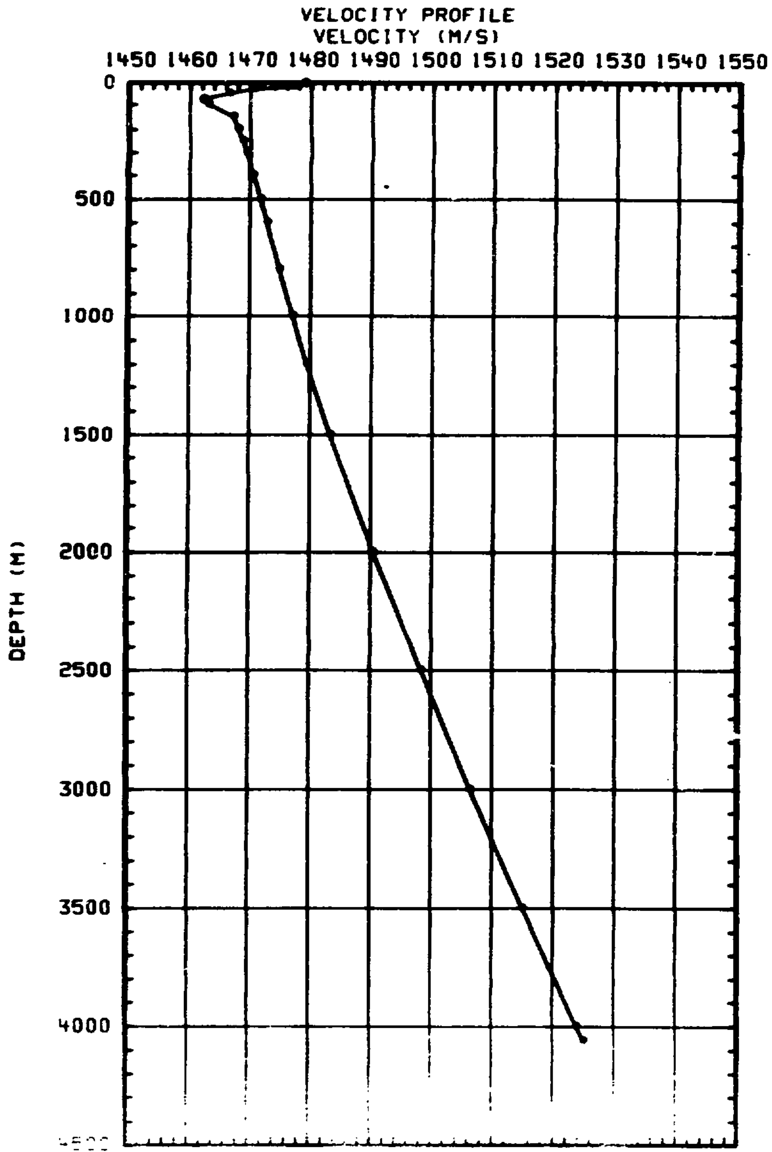
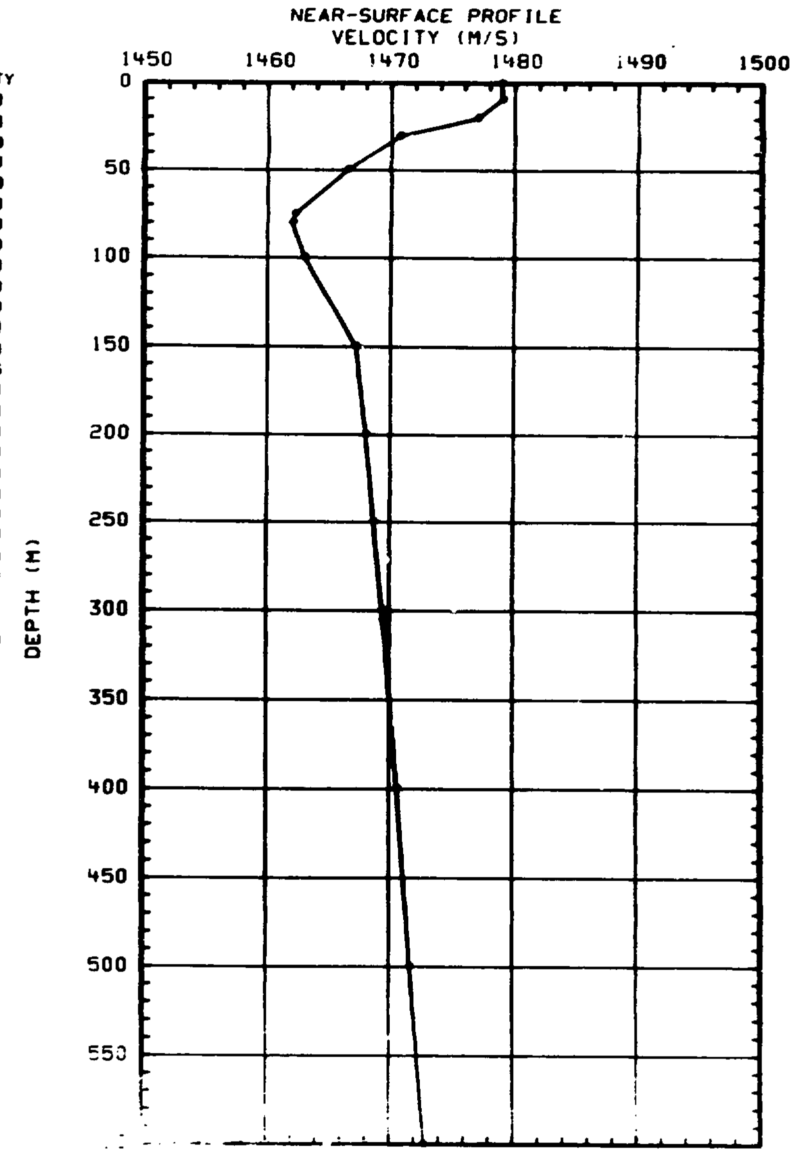
(U) Figure IIIH-6. Gulf of Alaska Run 112B Sound Speed Profile



DEPTH	VELOCITY
0.0	1478.90
10.0	1479.00
20.0	1477.00
30.0	1470.70
30.5	1470.59
50.0	1466.50
75.0	1462.20
80.0	1462.00
100.0	1463.00
150.0	1467.20
200.0	1468.00
250.0	1468.70
300.0	1469.40
305.0	1469.46
400.0	1470.50
500.0	1471.70
600.0	1472.80
800.0	1474.90
1000.0	1477.10
1200.0	1479.40
1500.0	1483.20
2000.0	1490.40
2500.0	1498.30
3000.0	1506.40
3500.0	1515.00
4000.0	1523.90
4060.0	1525.00



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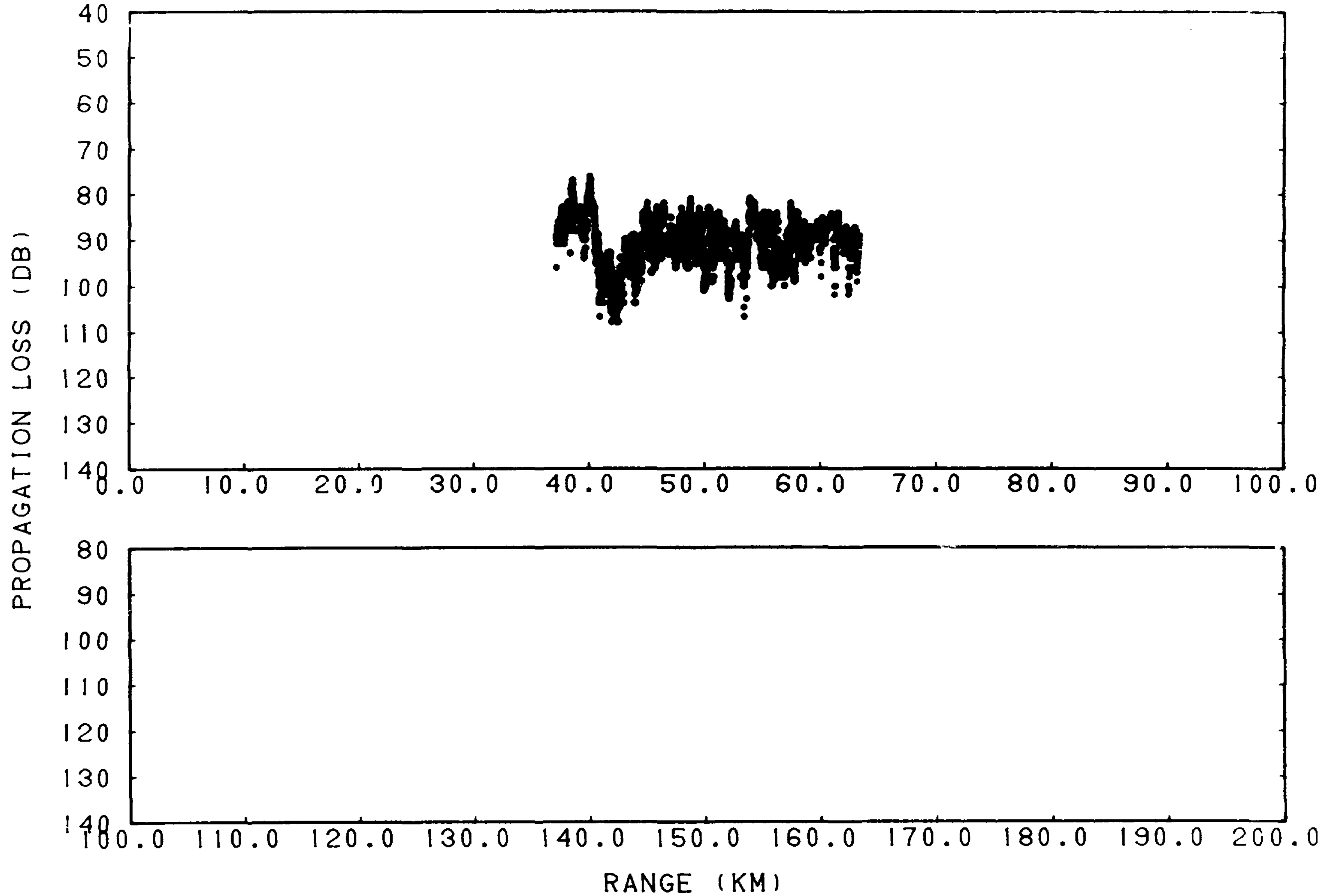
(U) Figure IIIH-7. Gulf of Alaska Run 112A Sound Speed Profile



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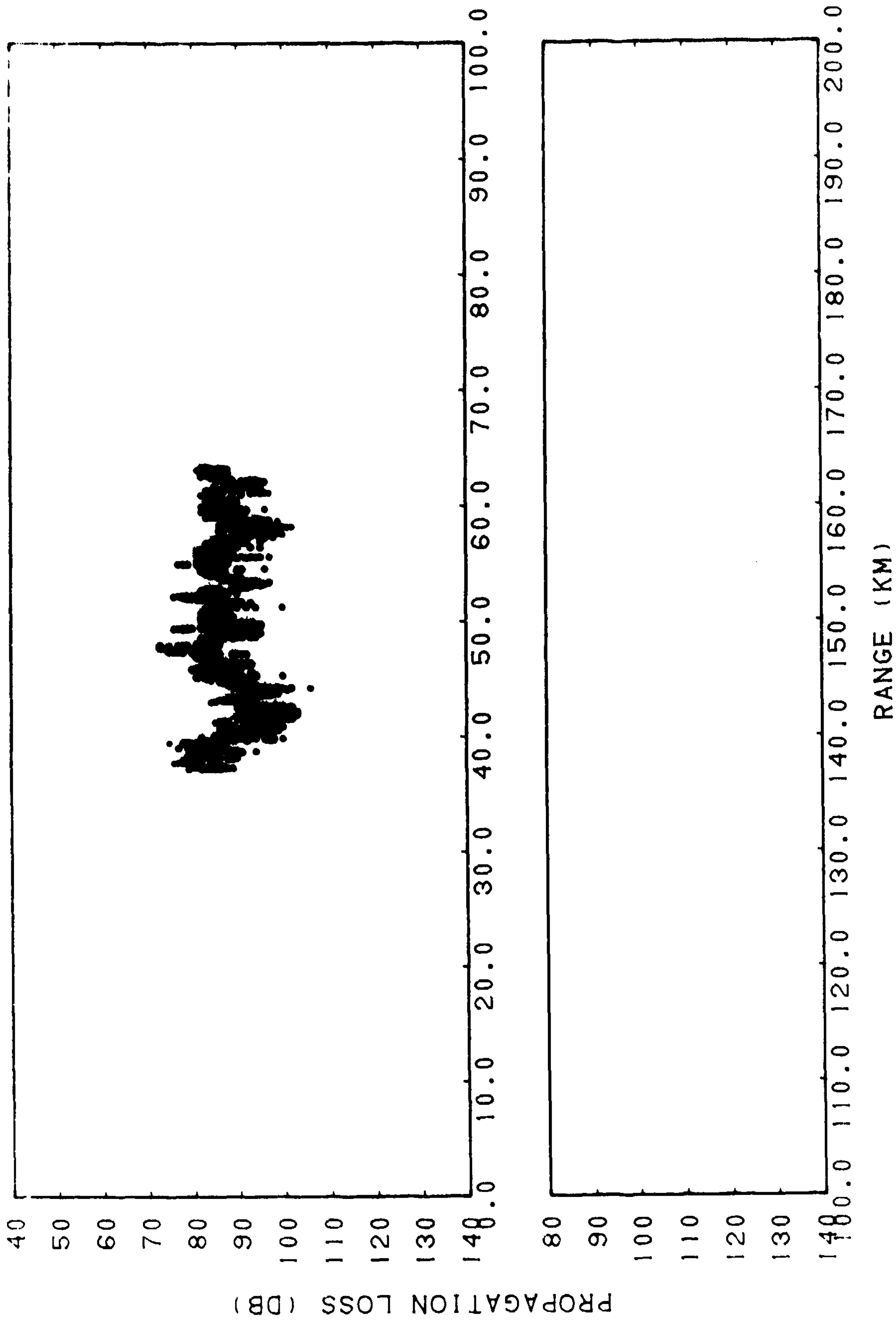
(C) Figure IIIH-8. Gulf of Alaska, Run 140, Source Depth = 30.5 Meters, Receiver Depth = 30.5 Meters, Frequency = 1.5 Kilohertz



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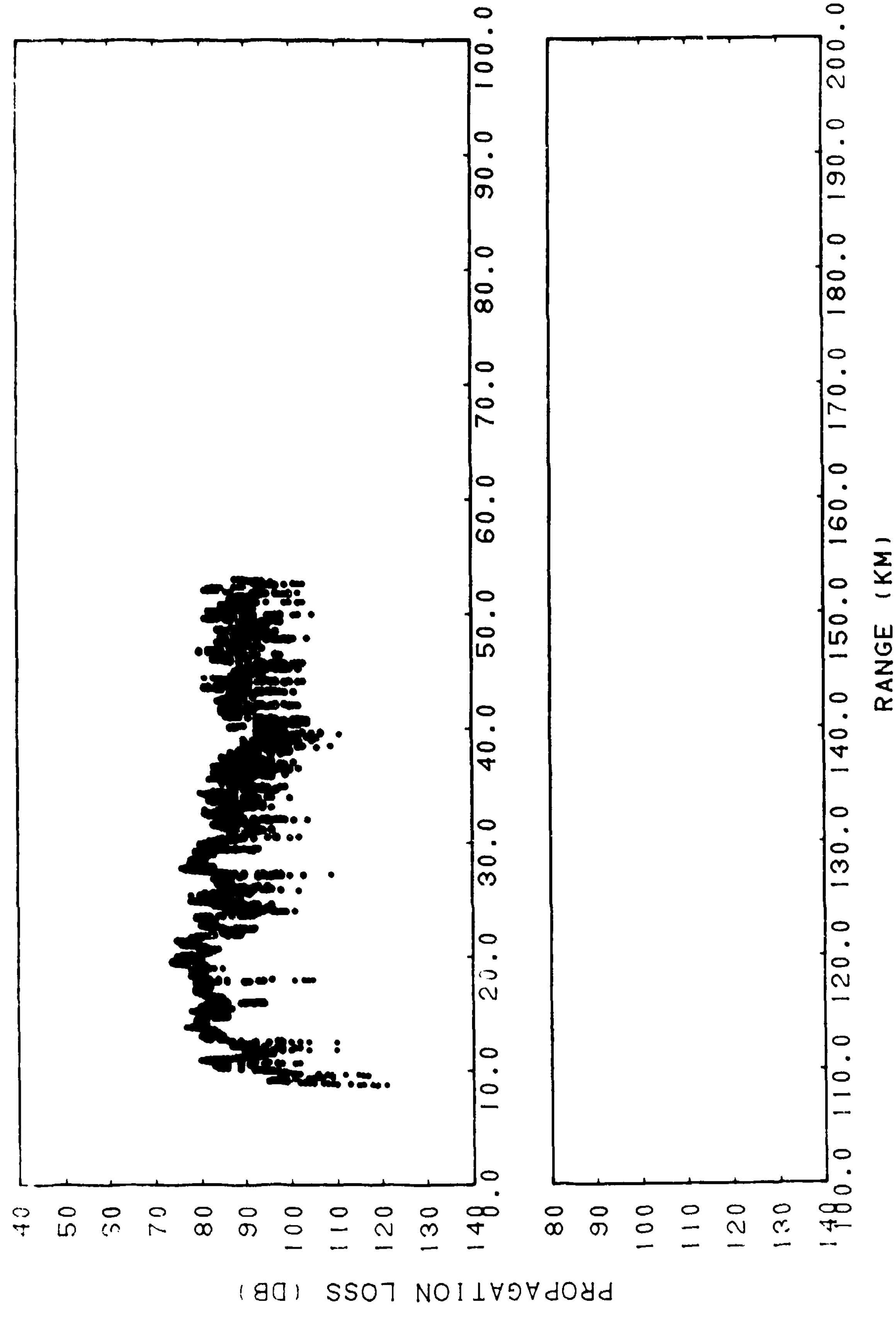
(C) Figure IIIH-9. Gulf of Alaska, Run 140, Source Depth = 30.5 Meters, Receiver Depth = 305 Meters, Frequency = 1.5 Kilohertz



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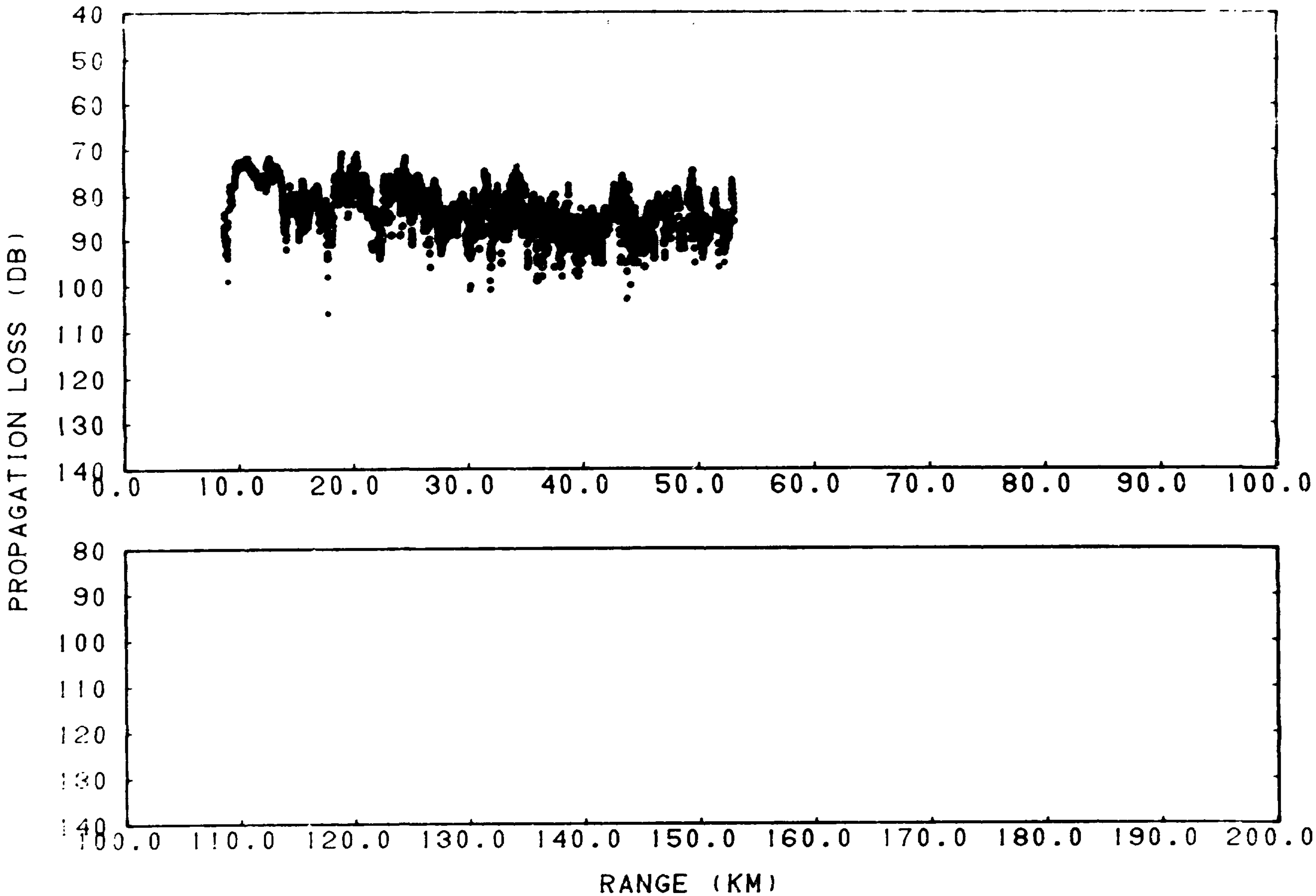
(C) Figure IIIH-10. Gulf of Alaska, Run 143, Source Depth = 30.5 Meters, Receiver Depth = 30.5 Meters, Frequency = 1.5 Kilohertz



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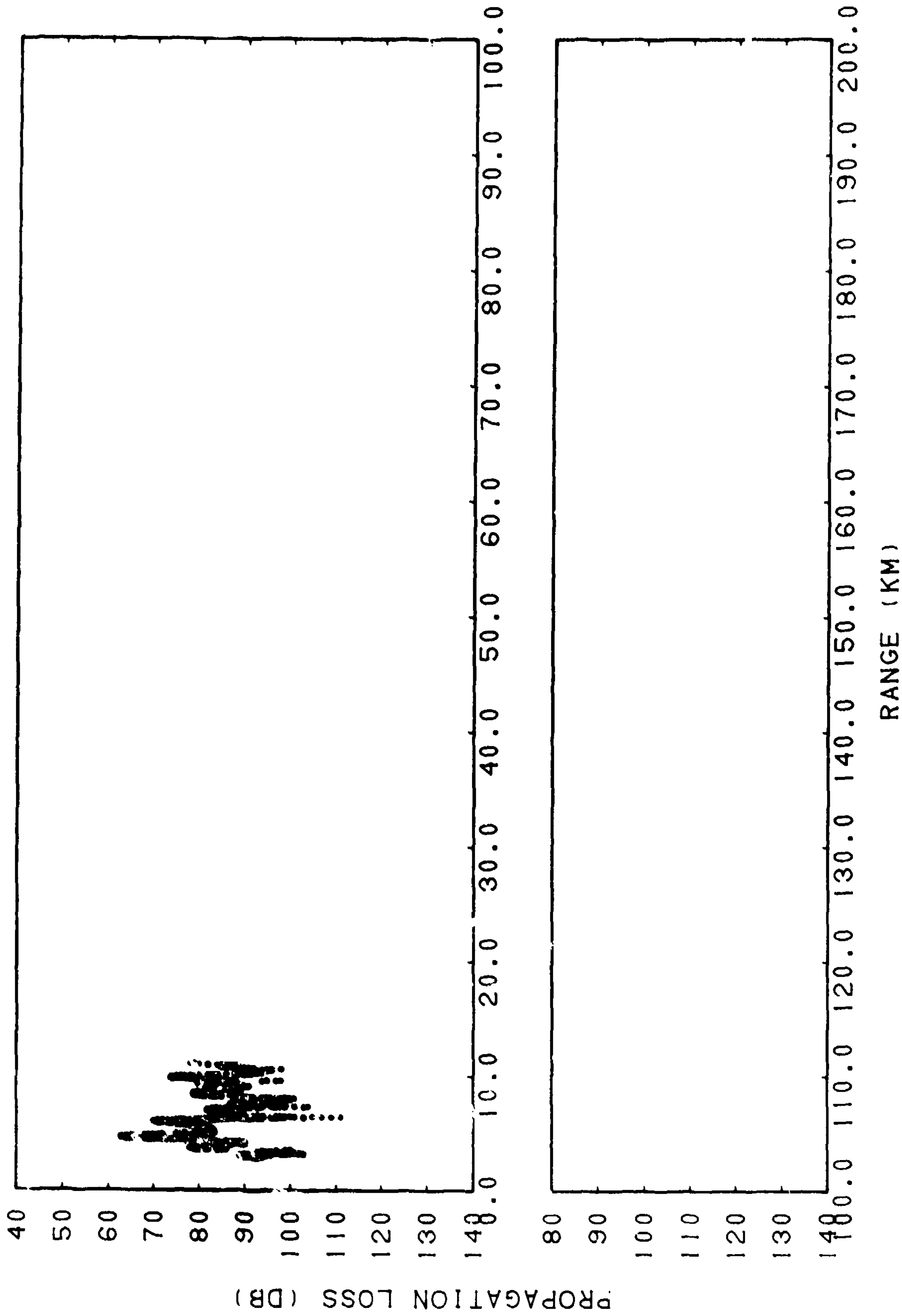
(C) Figure IIIH-11. Gulf of Alaska, Run 143, Source Depth = 30.5 Meters, Receiver Depth = 305 Meters, Frequency = 1.5 Kilohertz



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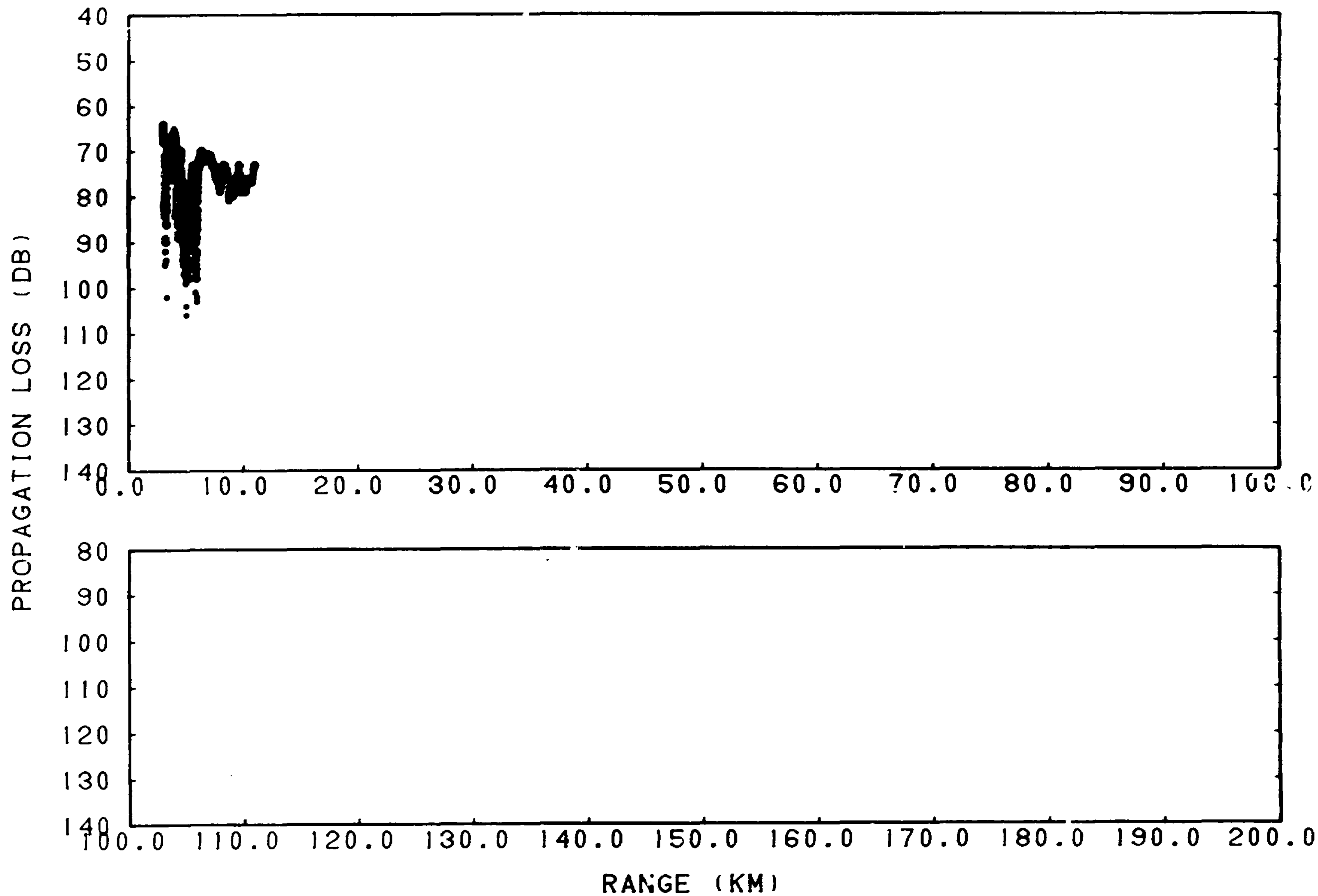
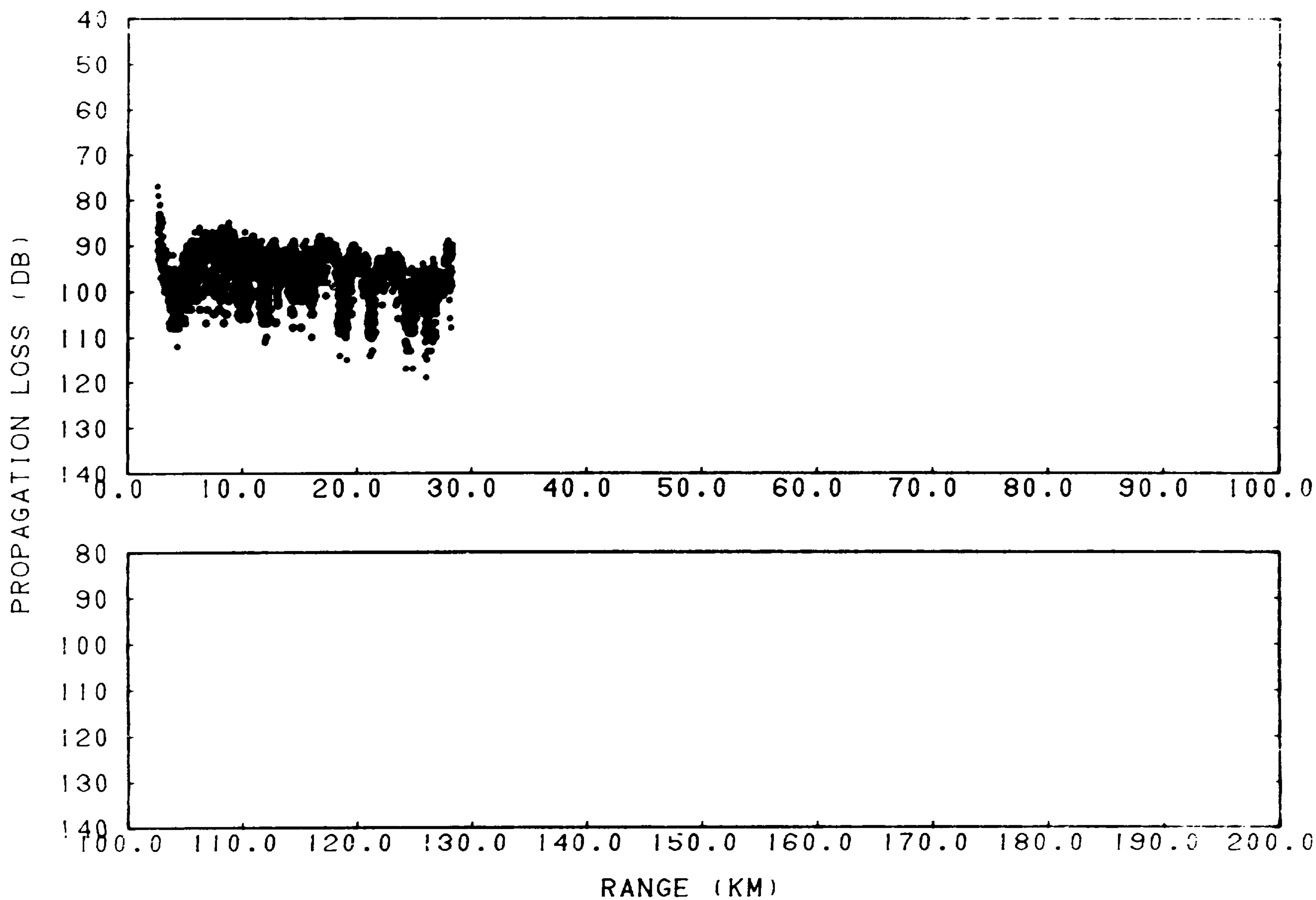
(C) Figure IIIH-12. Gulf of Alaska, Run 124, Source Depth = 30.5 Meters, Receiver Depth = 30.5 Meters, Frequency = 1.5 Kilohertz



CONFIDENTIAL

(C) Figure IIIH-13. Gulf of Alaska, Run 124, Source Depth = 30.5 Meters, Receiver Depth = 305 Meters, Frequency = 1.5 Kilohertz



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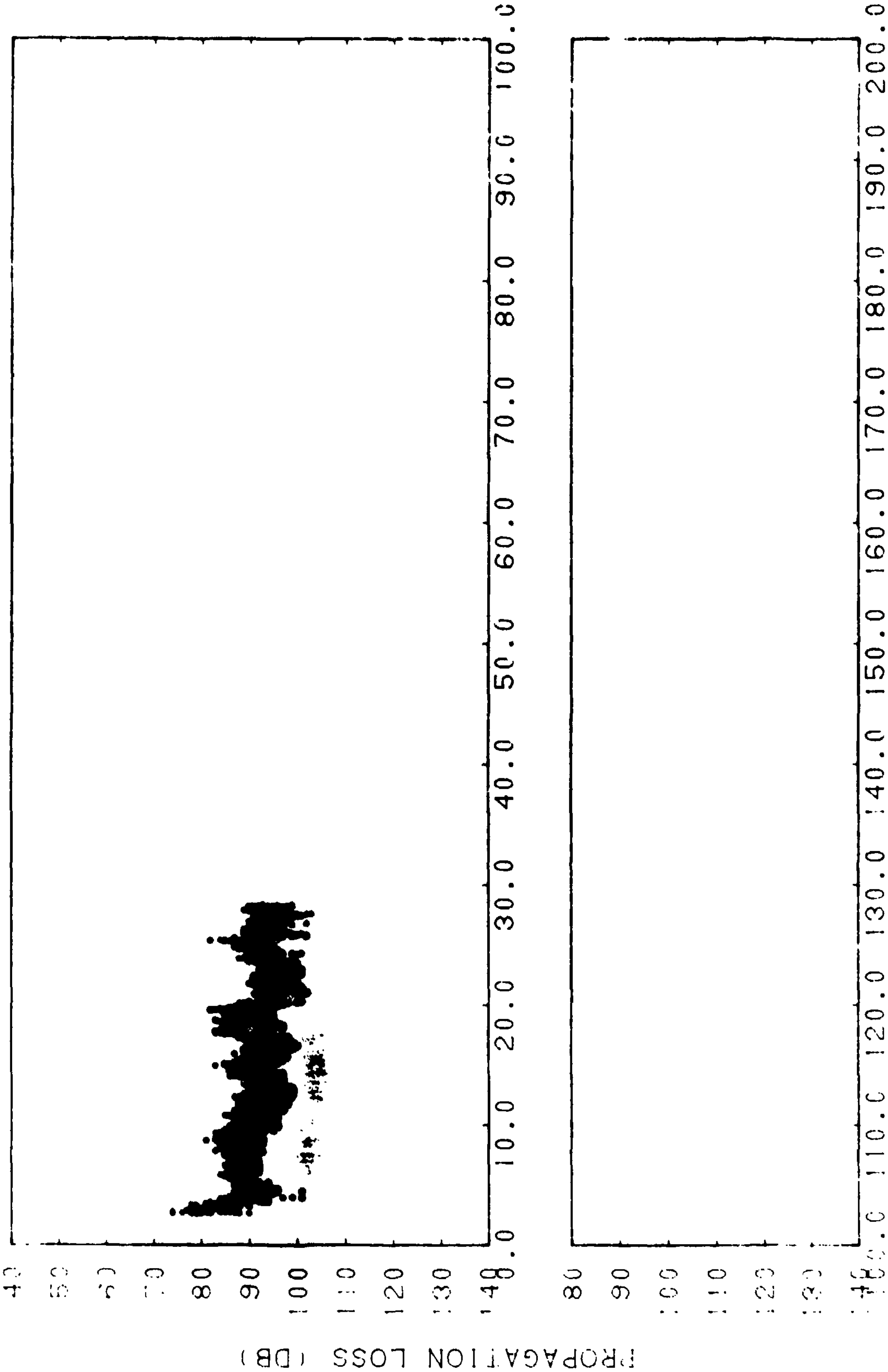
(C) Figure IIIH-14. Gulf of Alaska, Run 108, Source Depth = 1067 Meters, Receiver Depth = 30.5 Meters, Frequency = 2.5 Kilohertz



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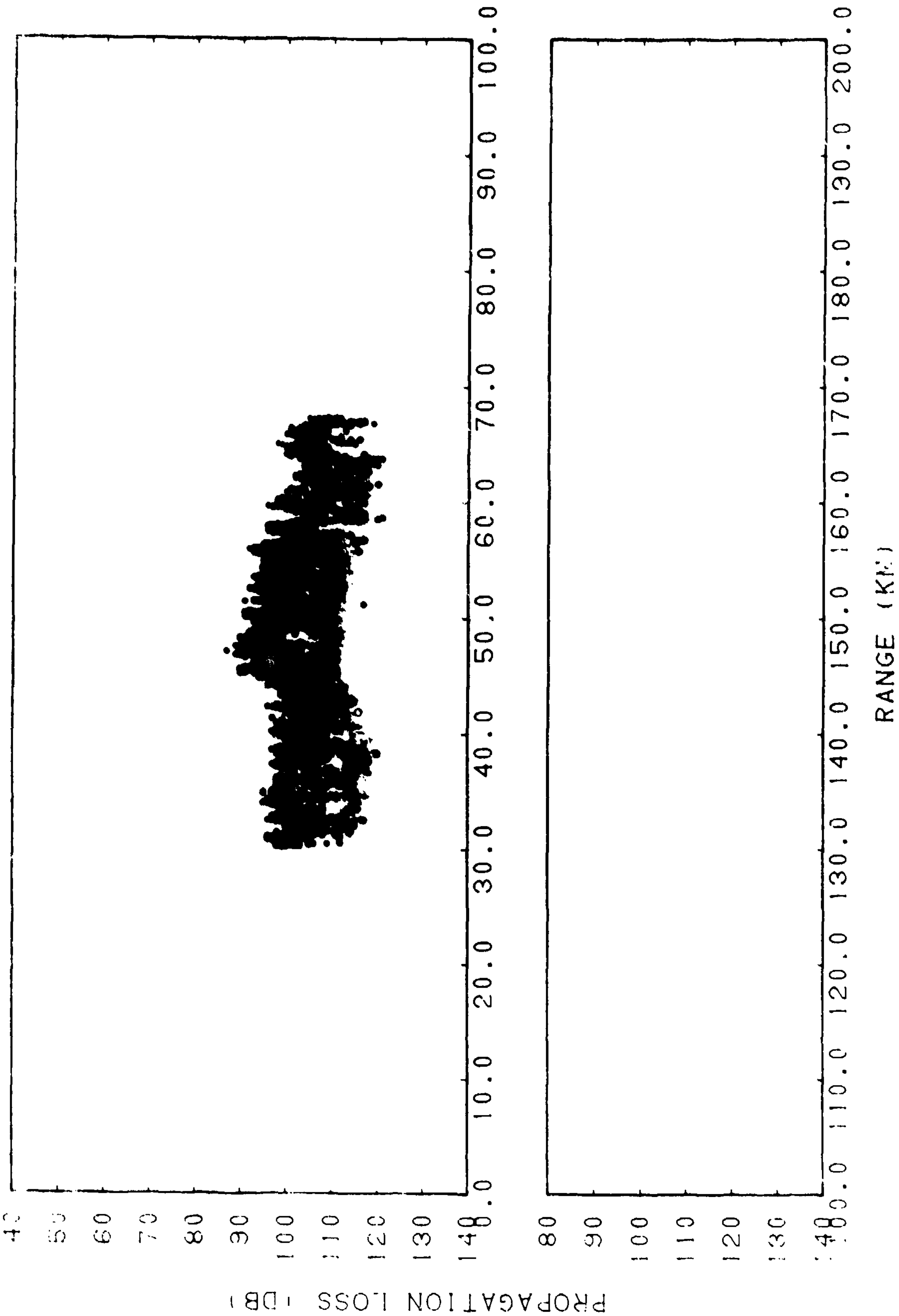
(C) Figure IIIH-15. Gulf of Alaska, Run 108, Source Depth = 1067 Meters, Receiver Depth = 305 Meters, Frequency = 2.5 Kilohertz



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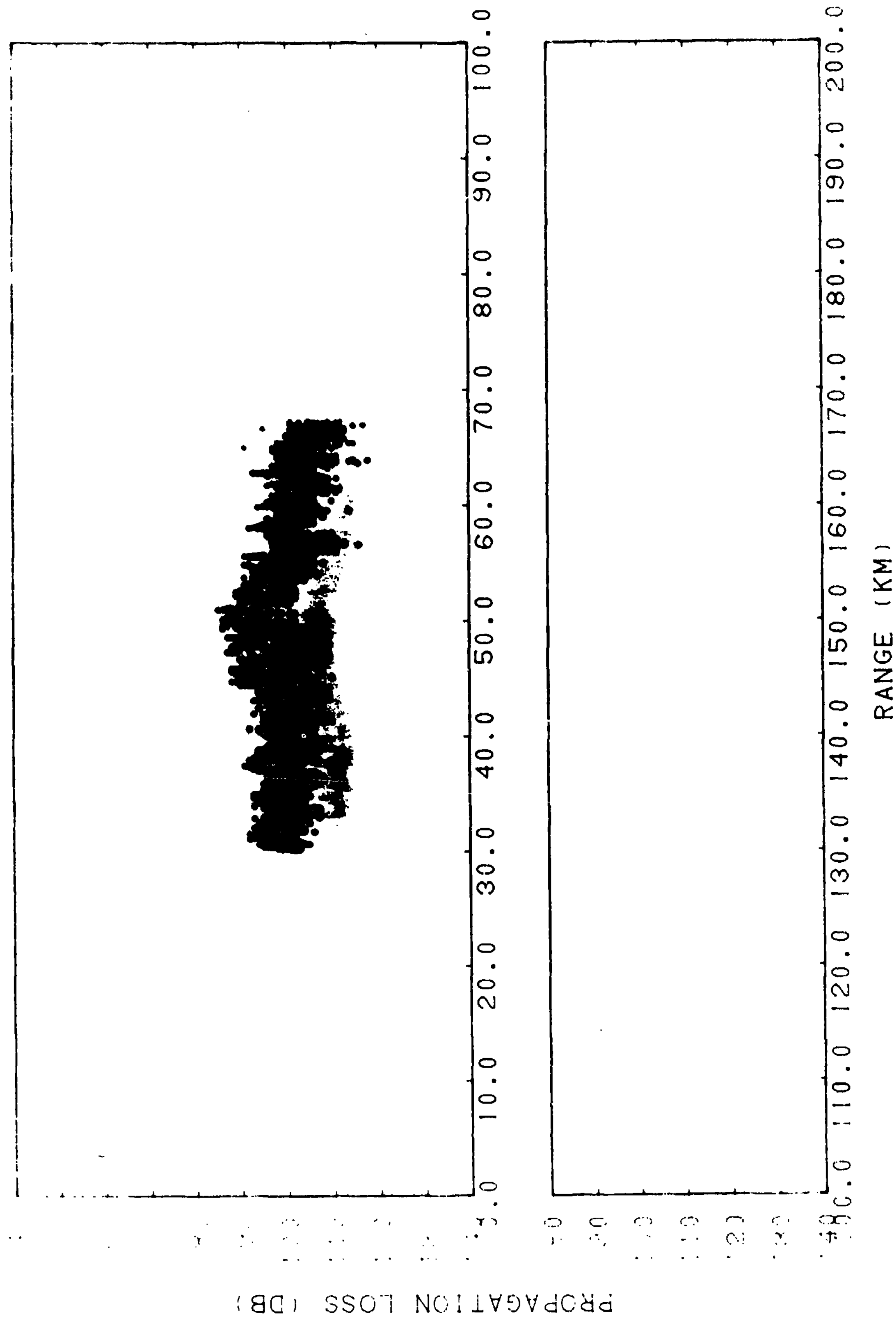
(C) Figure IIIH-16. Gulf of Alaska, Run 107, Source Depth = 1067 Meters, Receiver Depth = 30.5 Meters, Frequency = 2.5 Kilohertz



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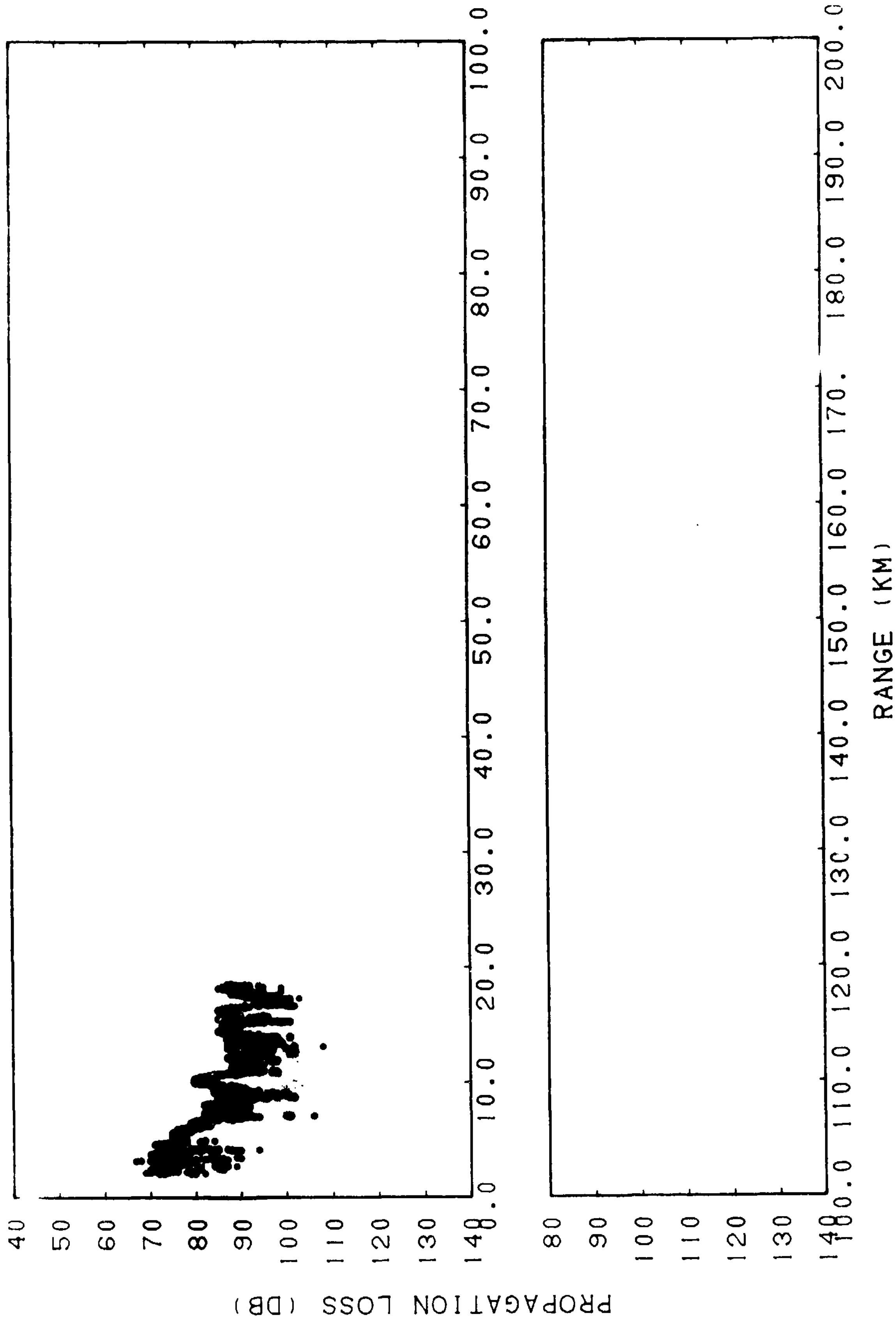
(C) Figure IIIH-17. Gulf of Alaska, Run 107, Source Depth = 1067 Meters, Receiver Depth = 305 Meters, Frequency = 2.5 Kilohertz



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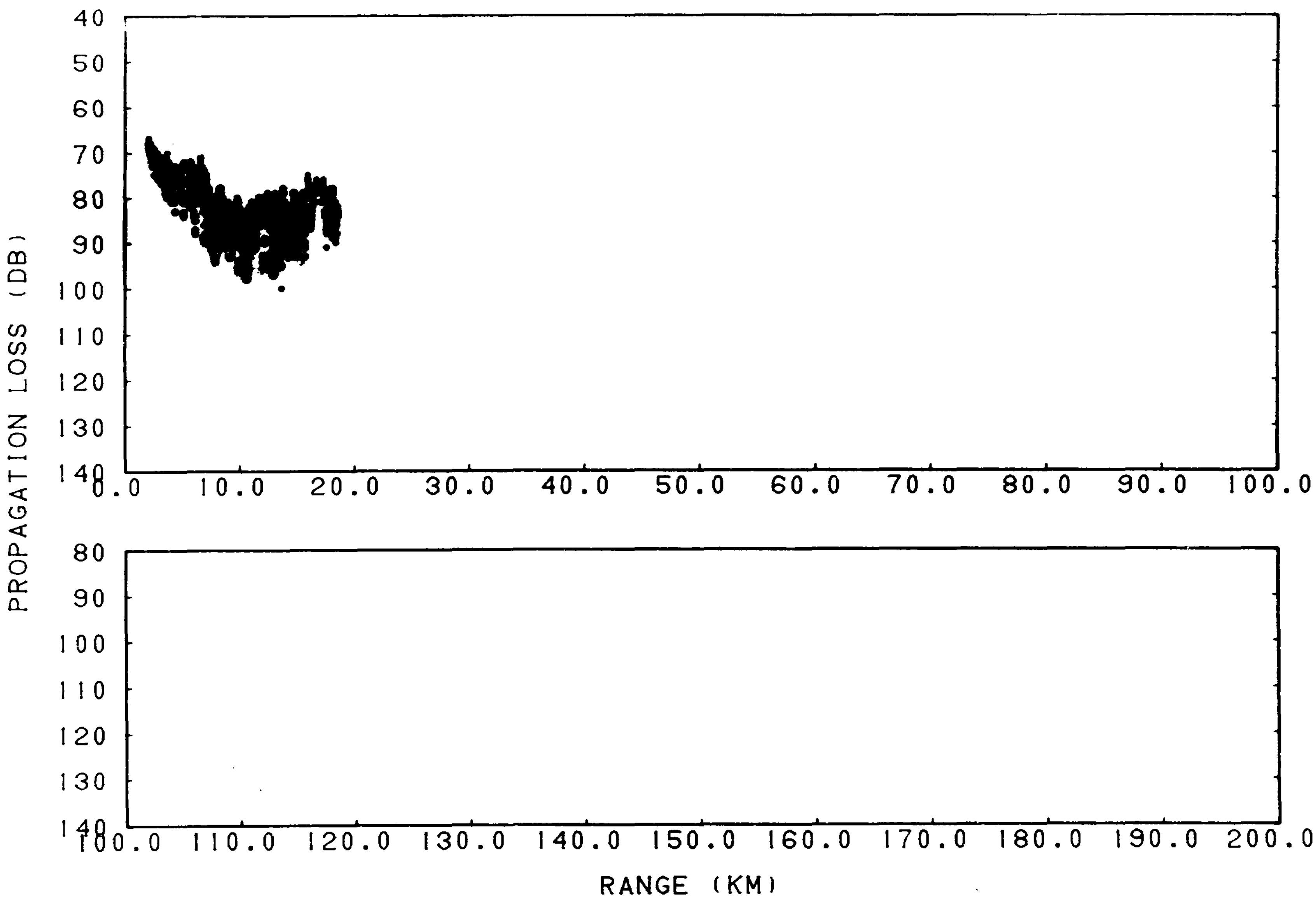
(C) Figure IIIH-18. Gulf of Alaska, Run 112B, Source Depth = 305 Meters, Receiver Depth = 30.5 Meters, Frequency = 2.5 Kilohertz



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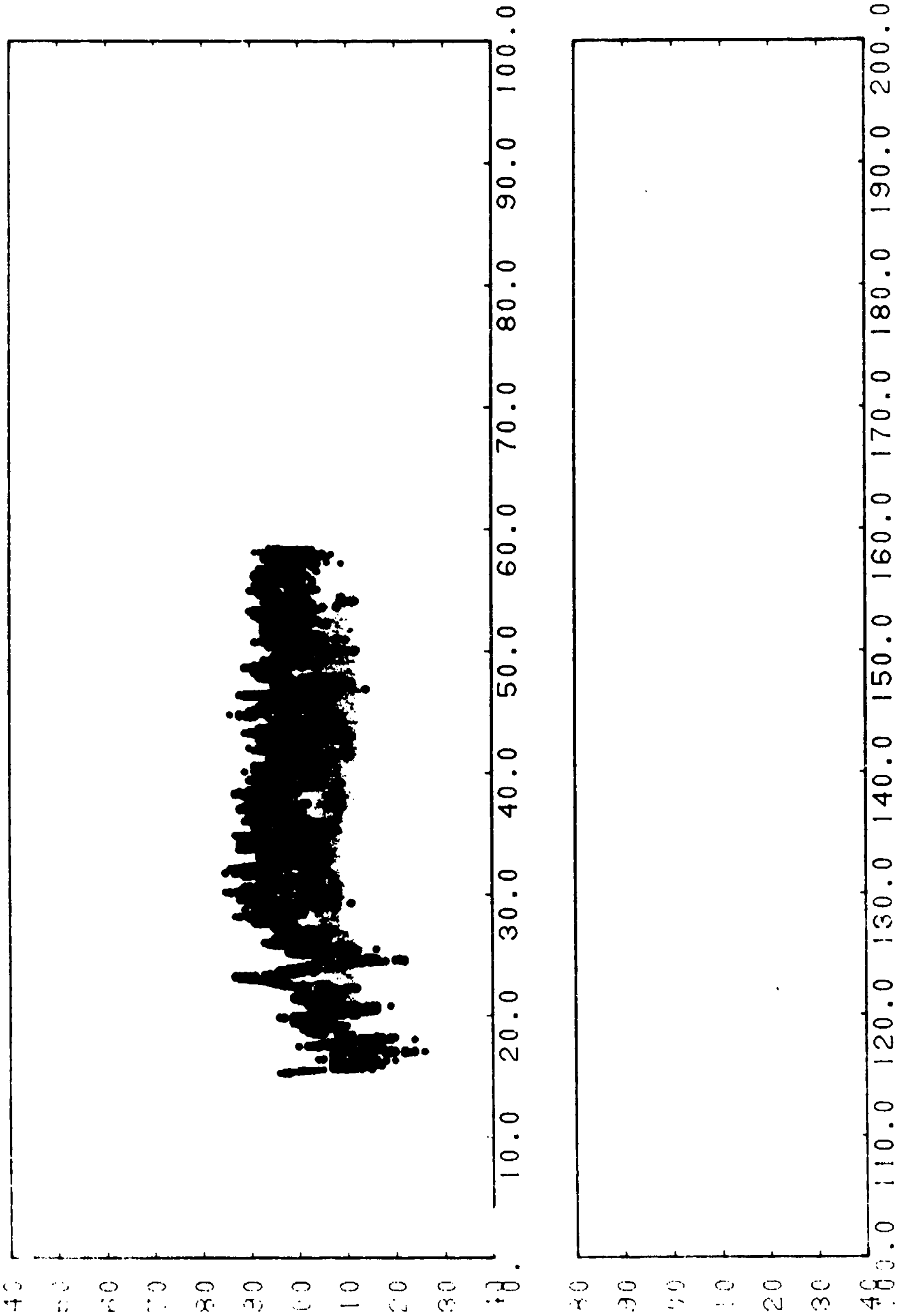
(C) Figure IIIH-19. Gulf of Alaska, Run 112B, Source Depth = 305 Meters, Receiver Depth = 305 Meters, Frequency = 2.5 Kilohertz



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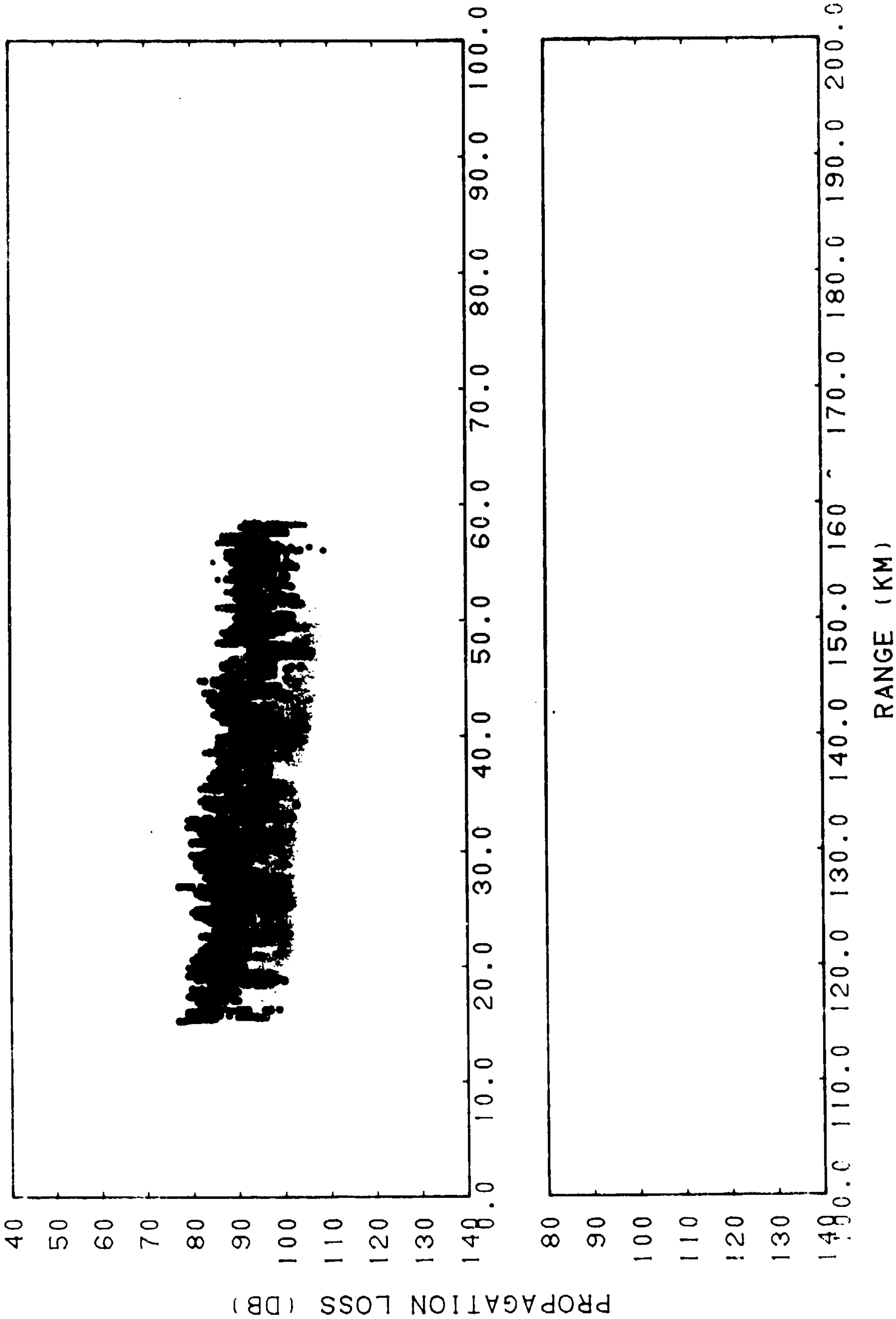
(C) Figure IIIH-20. Gulf of Alaska, Run 112A, Source Depth = 305 Meters, Receiver Depth = 30.5 Meters, Frequency = 2.5 Kilohertz



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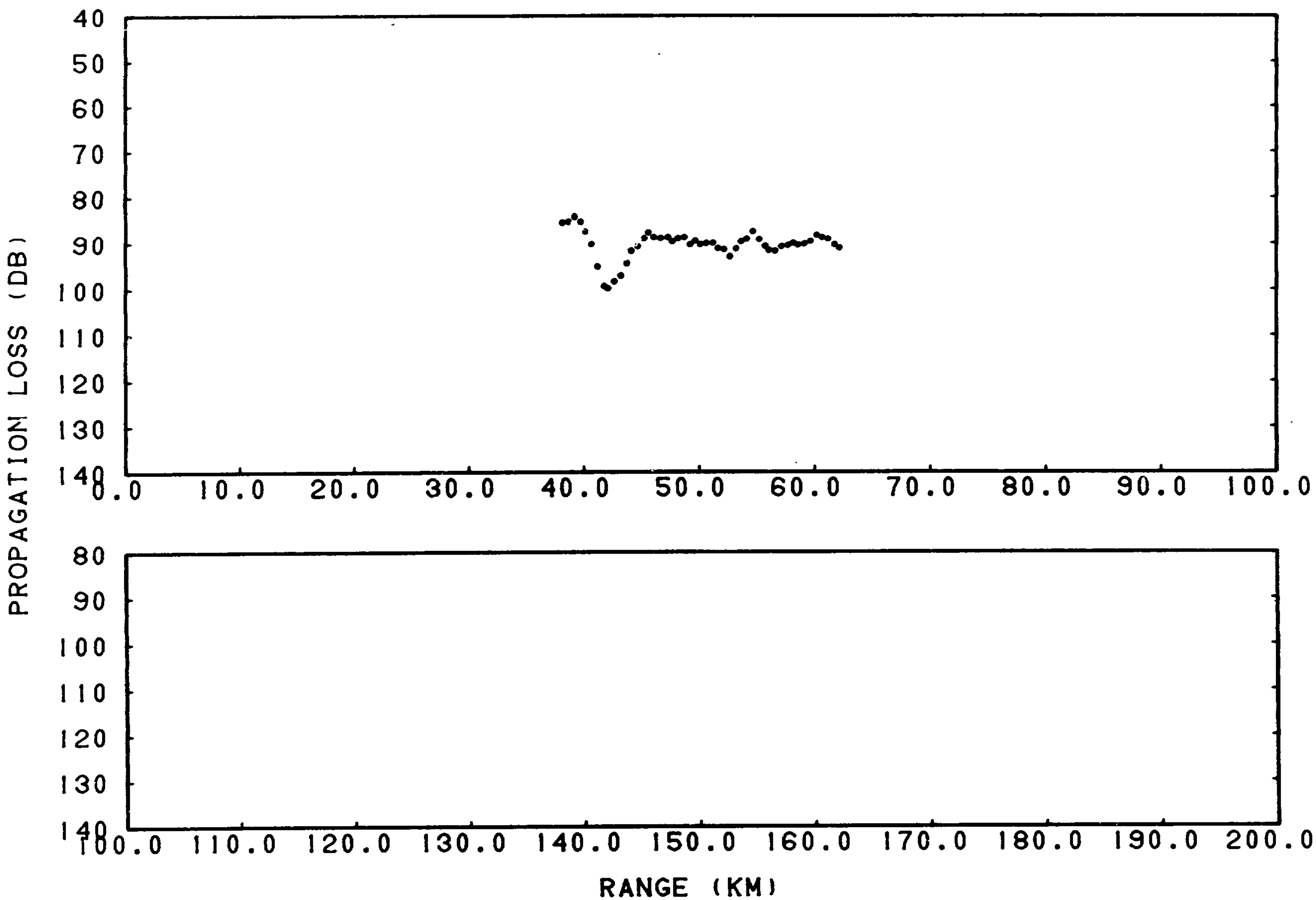
(C) Figure IIIH-21. Gulf of Alaska, Run 112A, Source Depth = 305 Meters, Receiver Depth = 305 Meters, Frequency = 2.5 Kilohertz



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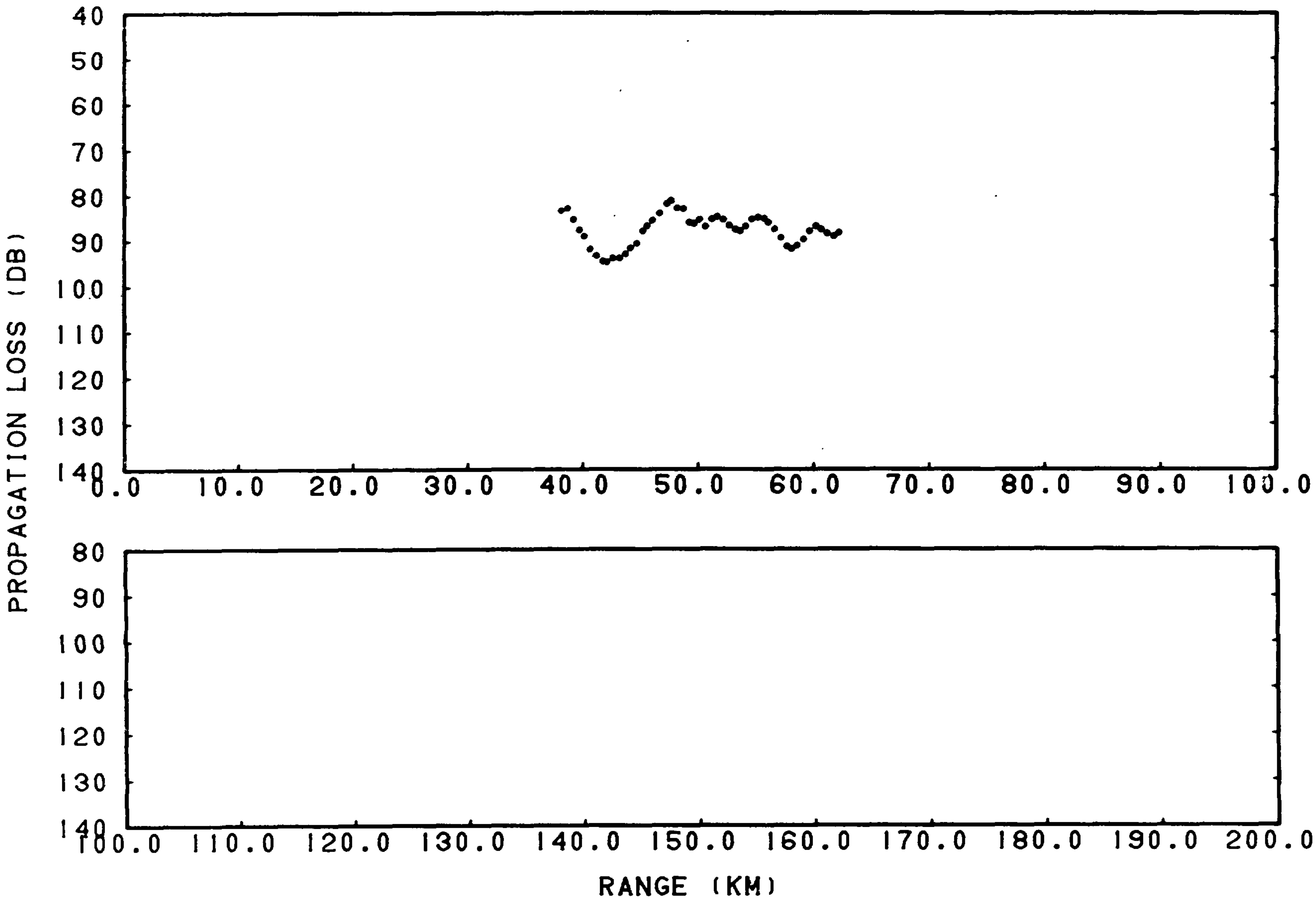
(C) Figure IIIH-22. Smoothed Gulf of Alaska, Run 140, Source Depth = 30.5 Meters, Receiver Depth = 30.5 Meters, Frequency = 1.5 Kilohertz



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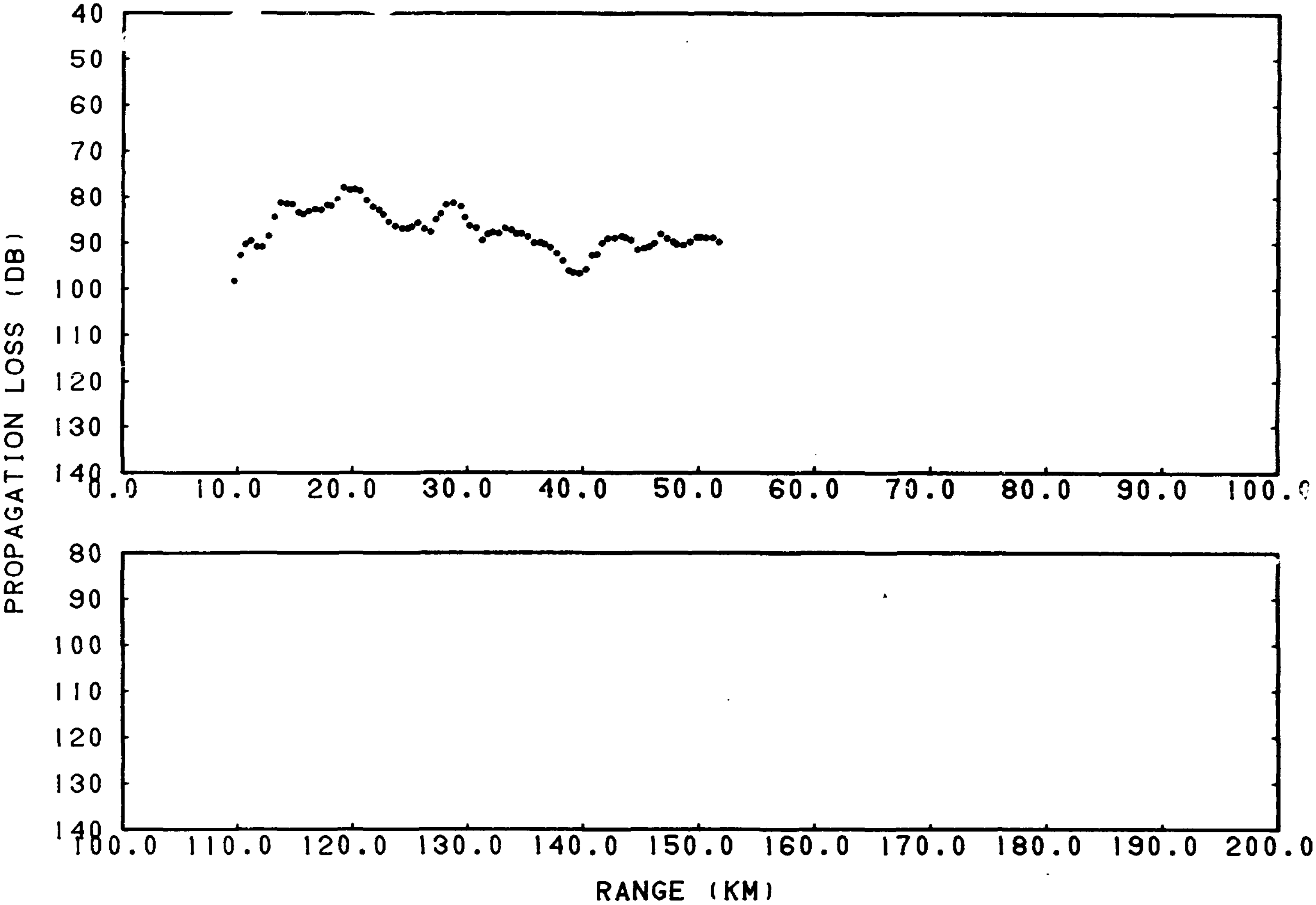
(C) Figure IIIH-23. Smoothed Gulf of Alaska, Run 140, Source Depth = 30.5 Meters, Receiver Depth = 305 Meters, Frequency = 1.5 Kilohertz



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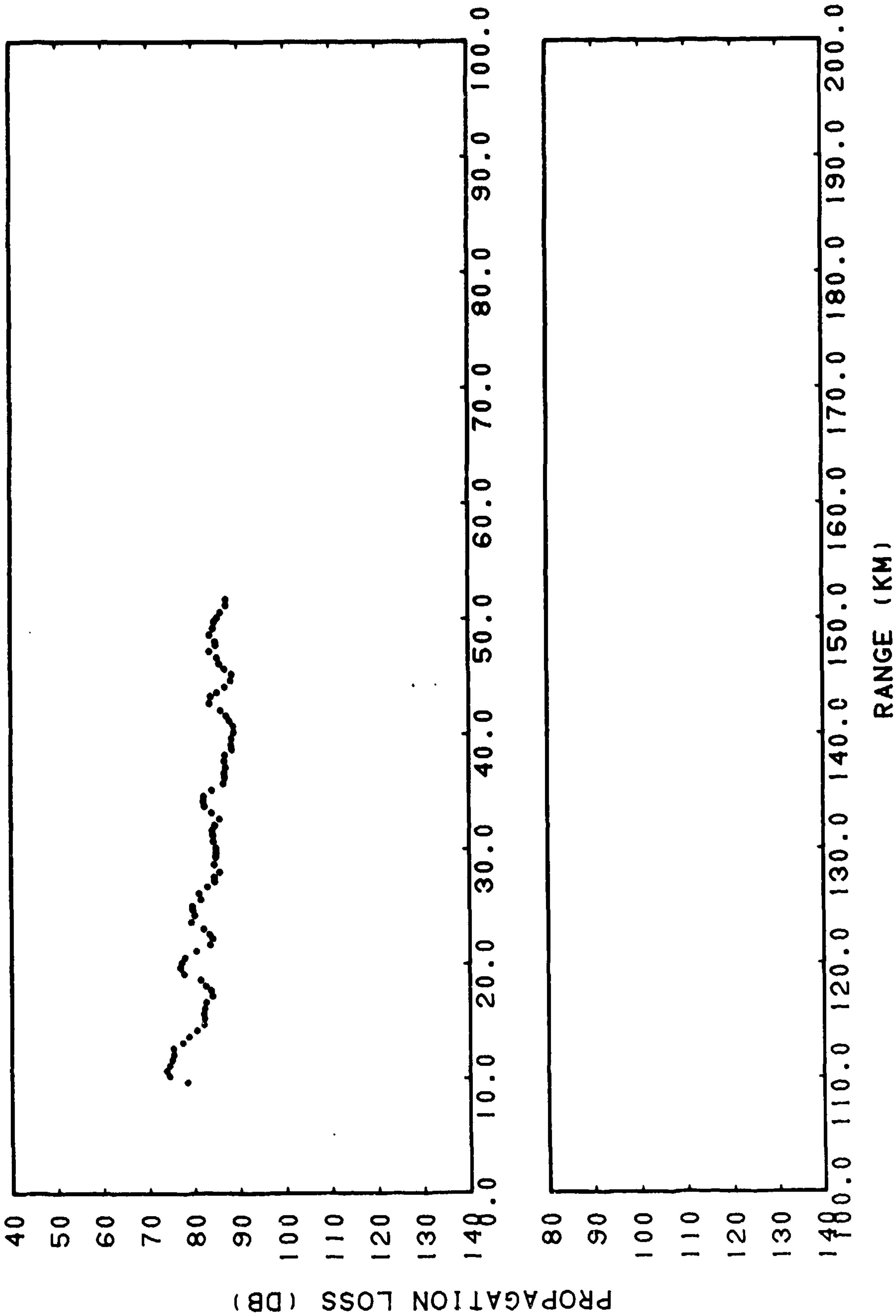
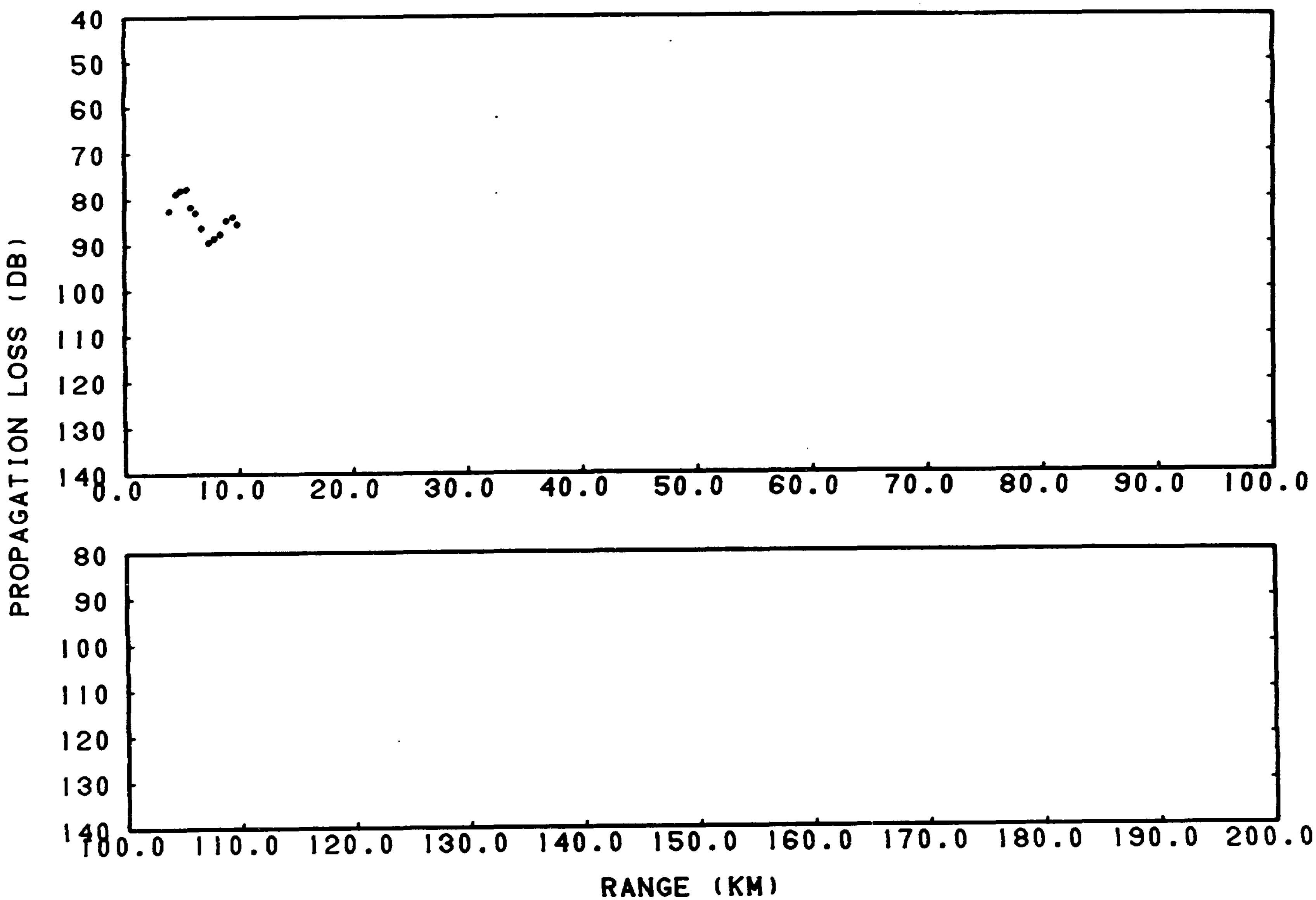
(C) Figure IIIH-24. Smoothed Gulf of Alaska, Run 143, Source Depth = 30.5 Meters, Receiver Depth = 30.5 Meters, Frequency = 1.5 Kilohertz



CONFIDENTIAL

(C) Figure IIIH-25. Smoothed Gulf of Alaska, Run 143, Source Depth = 30.5 Meters, Receiver Depth = 305 Meters, Frequency = 1.5 Kilohertz



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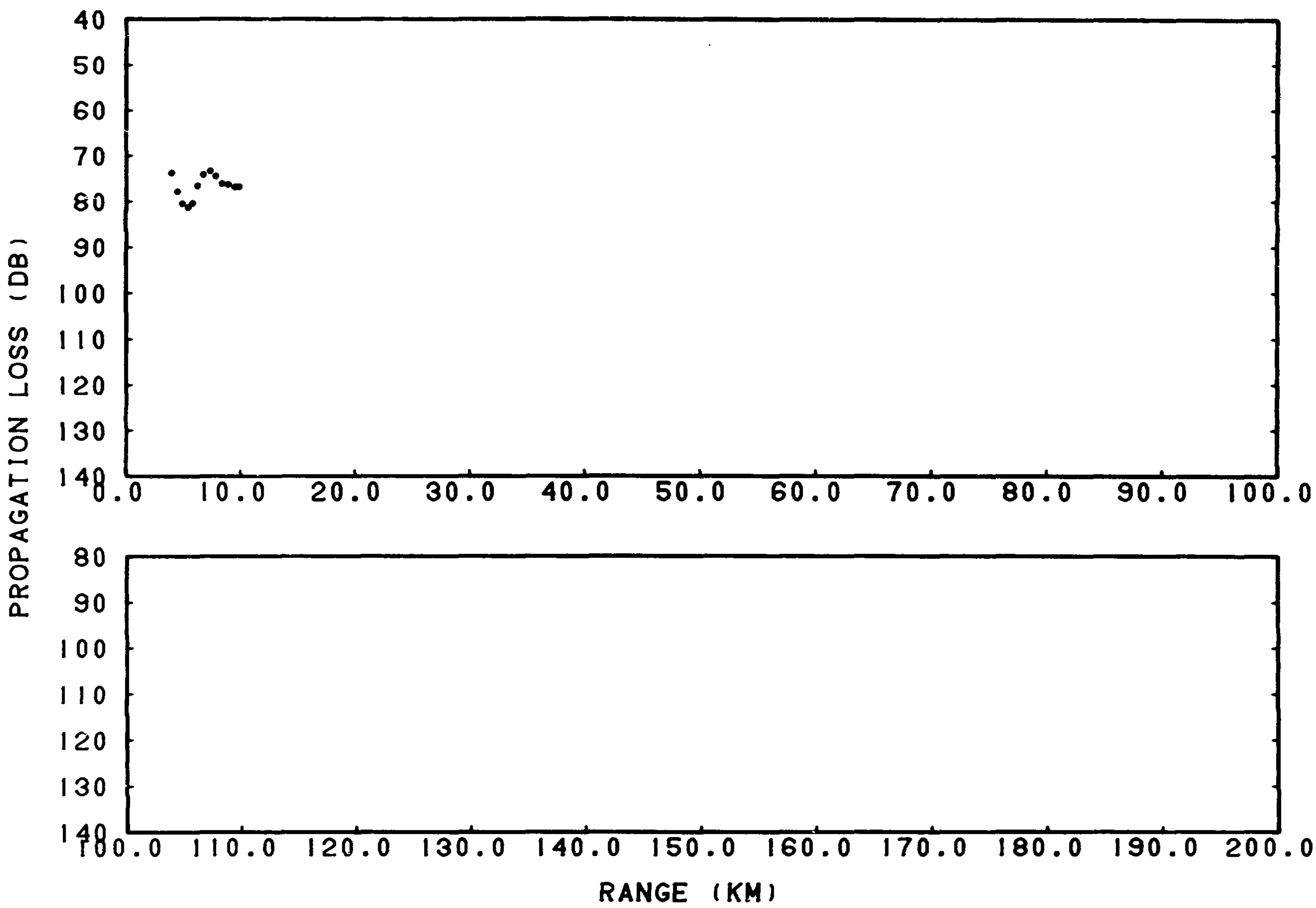
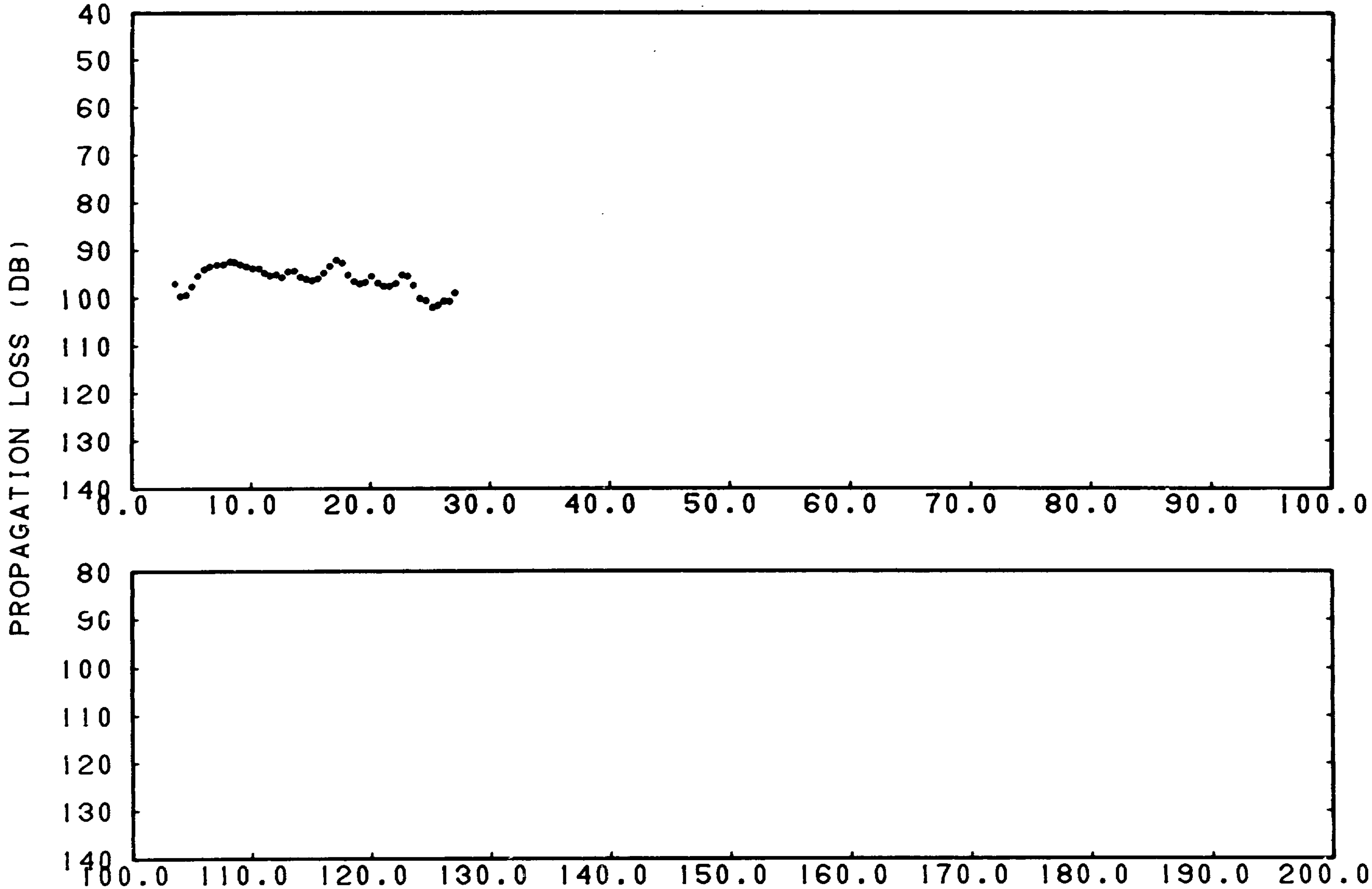
(C) Figure IIIH-26. Smoothed Gulf of Alaska, Run 124, Source Depth = 30.5 Meters, Receiver Depth = 30.5 Meters, Frequency = 1.5 Kilohertz



CONFIDENTIAL

(C) Figure IIIH-27. Smoothed Gulf of Alaska, Run 124, Source Depth = 30.5 Meters, Receiver Depth = 305 Meters, Frequency = 1.5 Kilohertz



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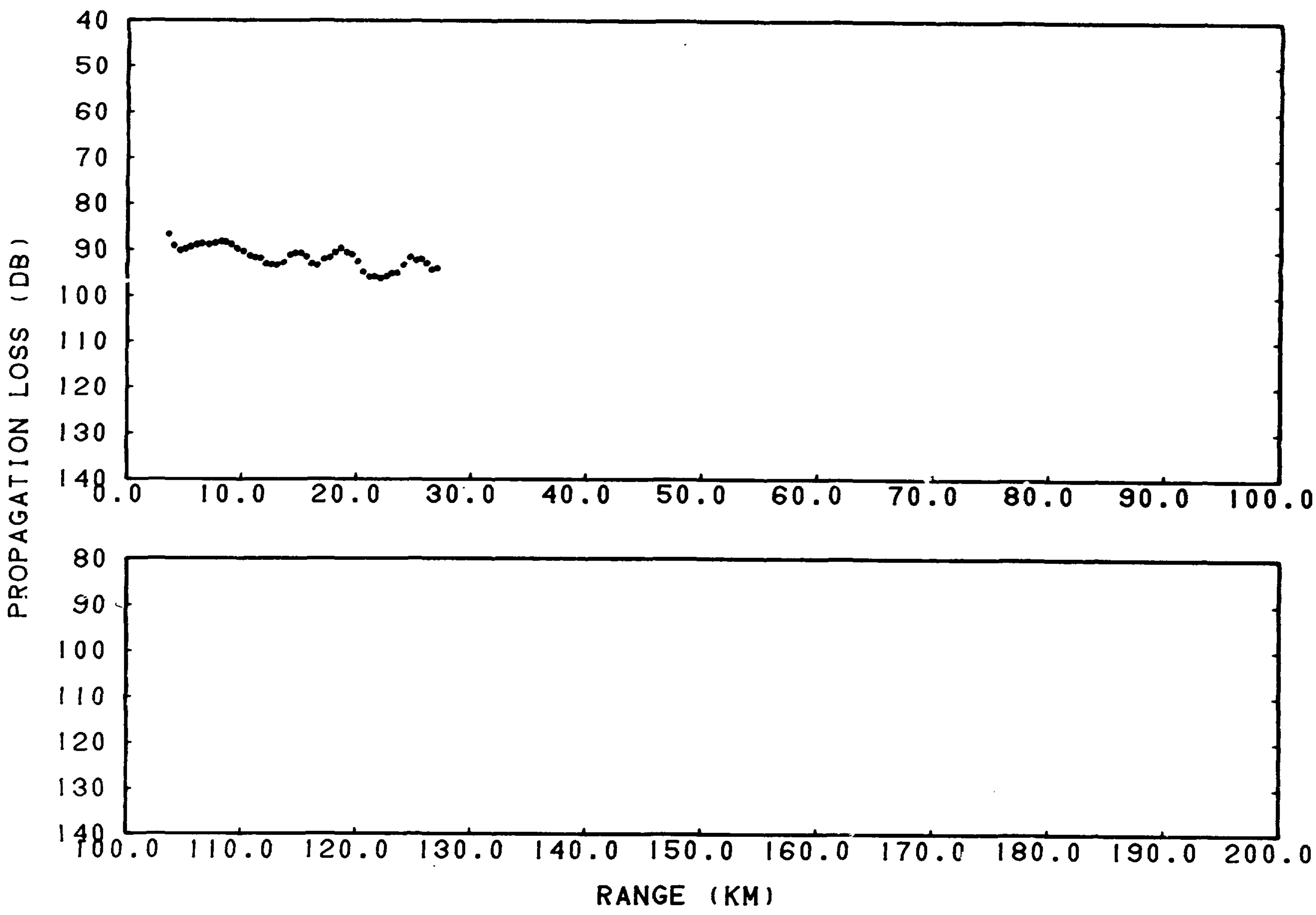
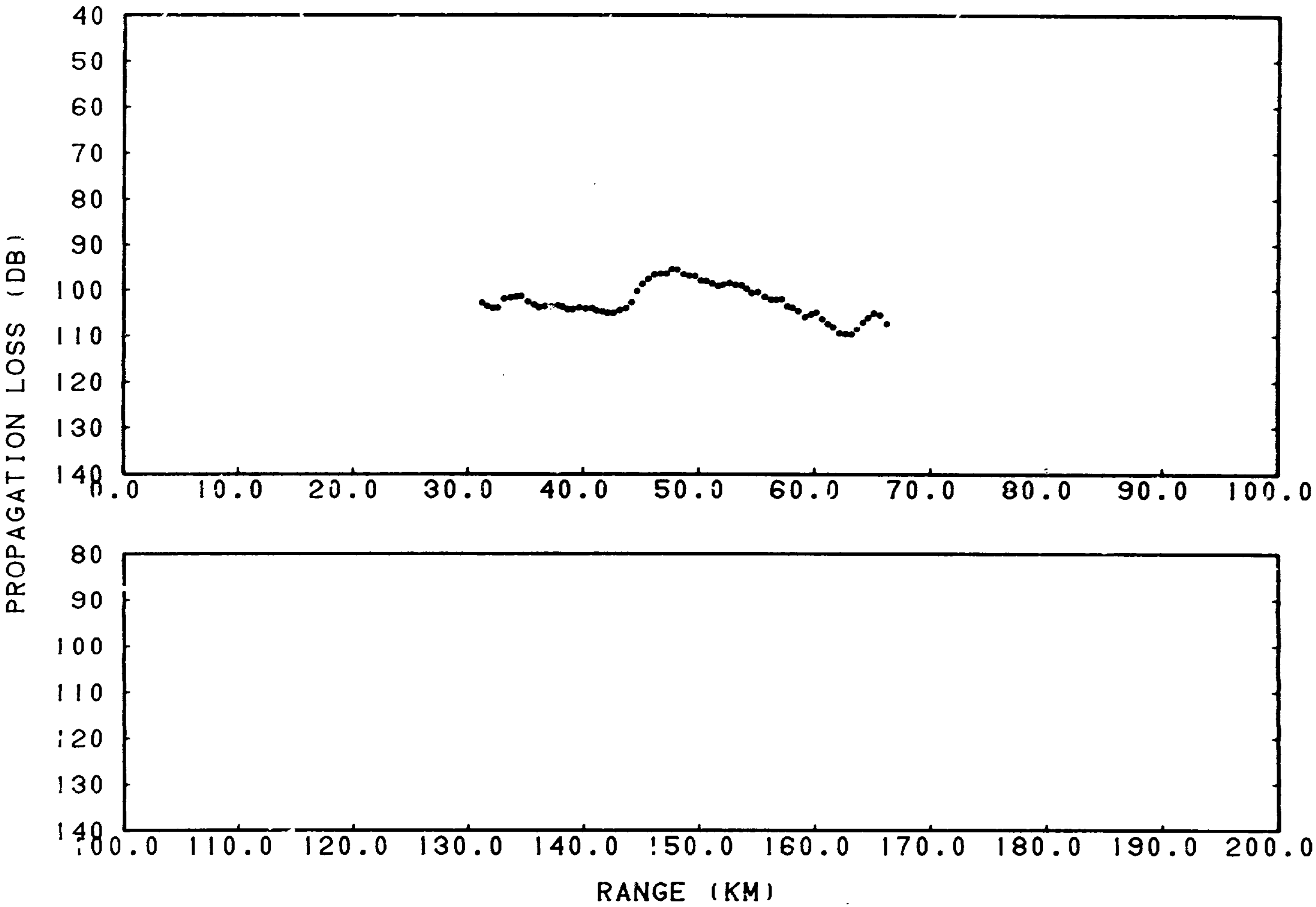
(C) Figure IIIH-28. Smoothed Gulf of Alaska, Run 108, Source Depth = 1067 Meters, Receiver Depth = 30.5 Meters, Frequency = 2.5 Kilohertz



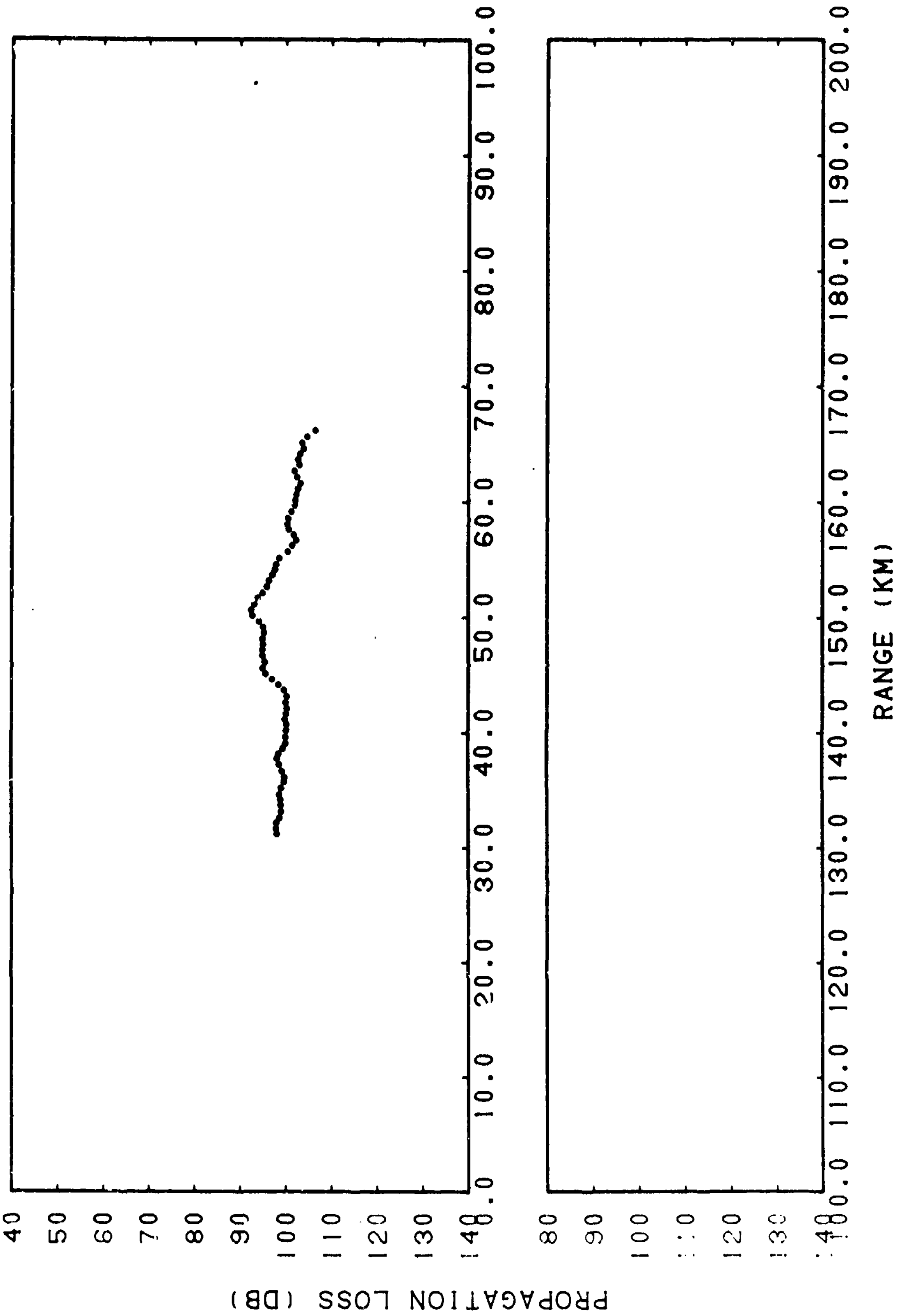
CONFIDENTIAL

(C) Figure IIIH-29. Smoothed Gulf of Alaska, Run 108, Source Depth = 1067 Meters, Receiver Depth = 305 Meters, Frequency = 2.5 Kilohertz



CONFIDENTIAL

(C) Figure IIIH-30. Smoothed Gulf of Alaska, Run 107, Source Depth = 1067 Meters, Receiver Depth = 30.5 Meters, Frequency = 2.5 Kilohertz



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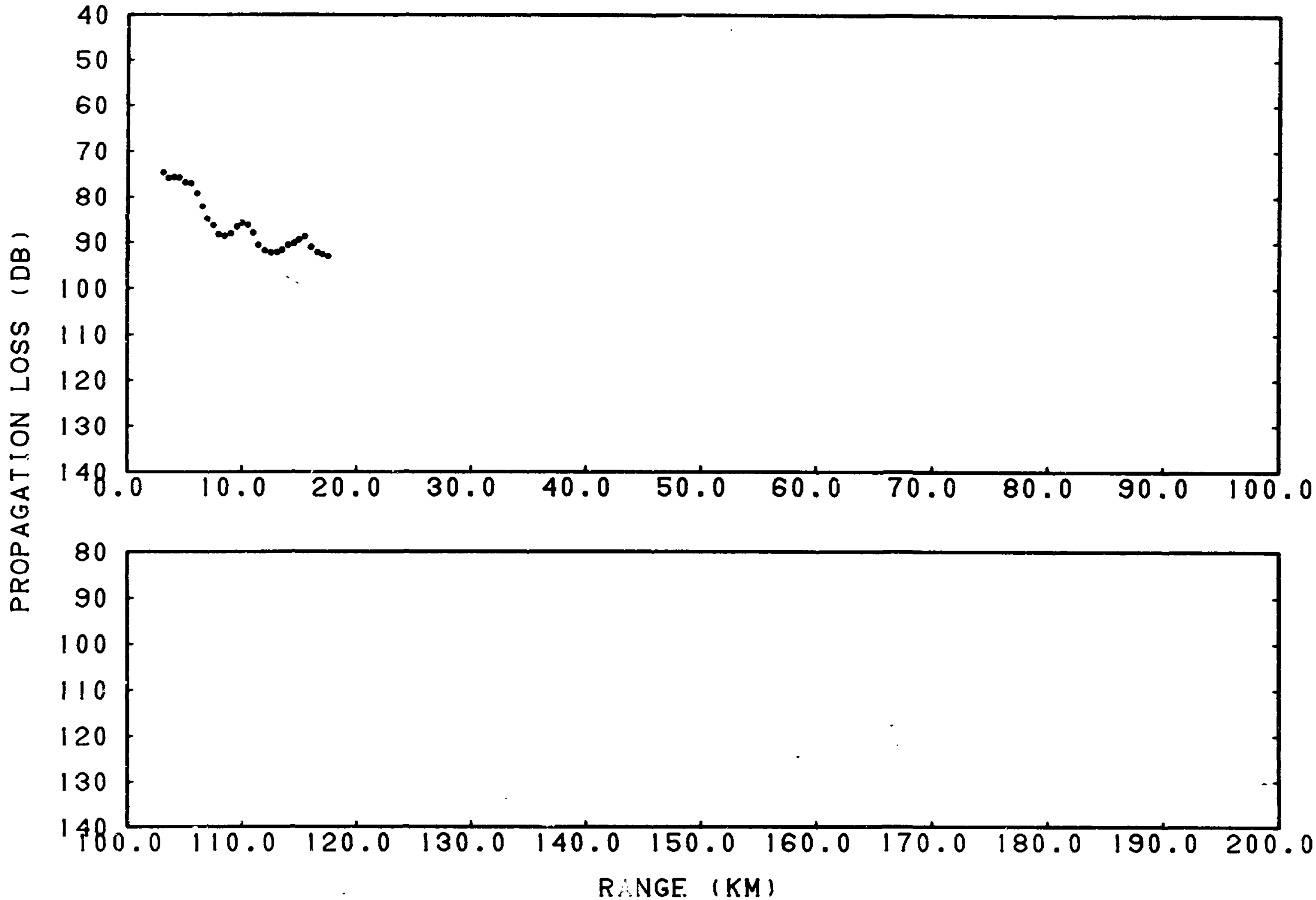
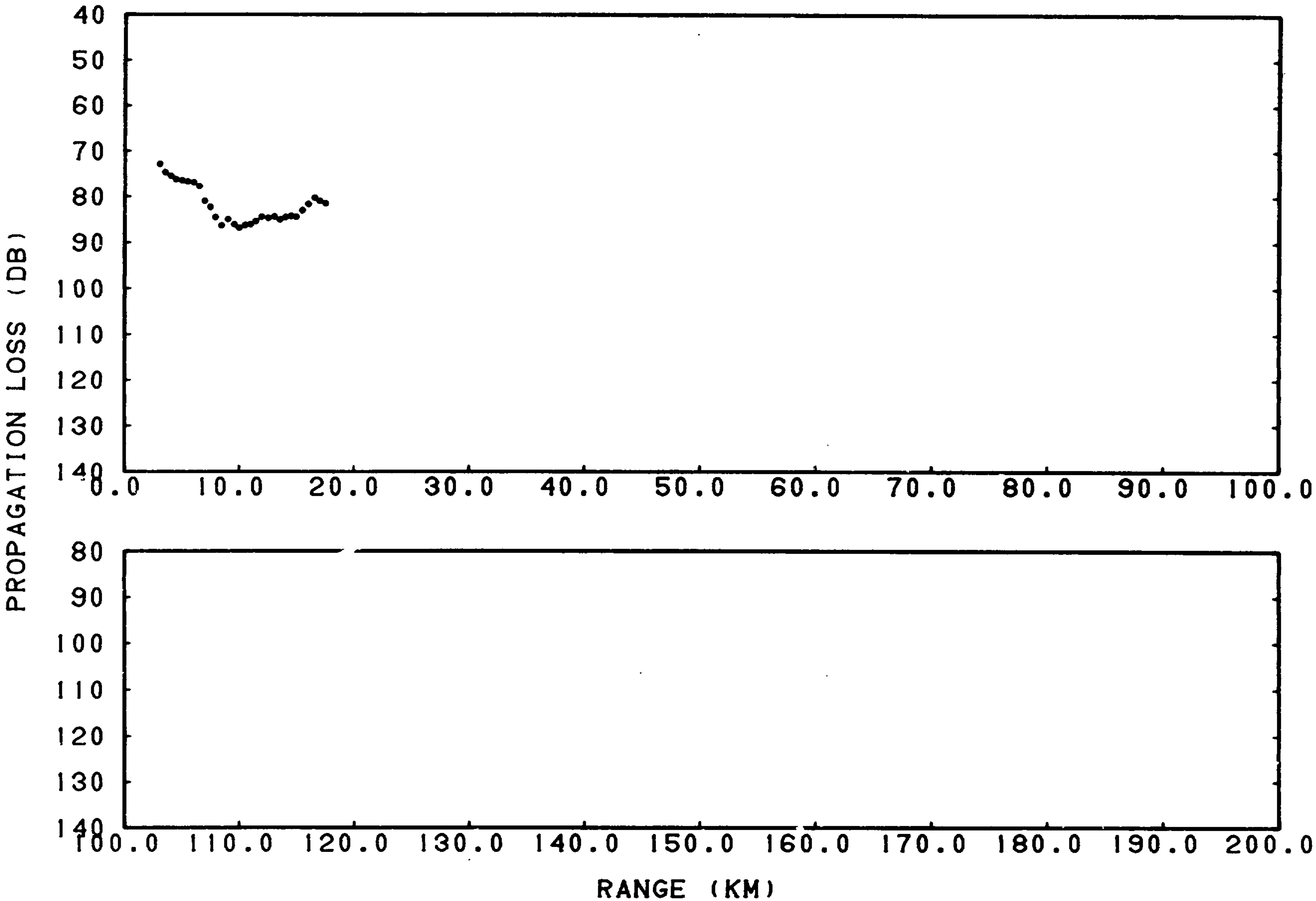
(C) Figure IIIH-31. Smoothed Gulf of Alaska, Run 107, Source Depth = 1067 Meters, Receiver Depth = 305 Meters, Frequency = 2.5 Kilohertz



CONFIDENTIAL

(C) Figure IIIH-32. Smoothed Gulf of Alaska, Run 112B, Source Depth = 305 Meters, Receiver Depth = 30.5 Meters, Frequency = 2.5 Kilohertz



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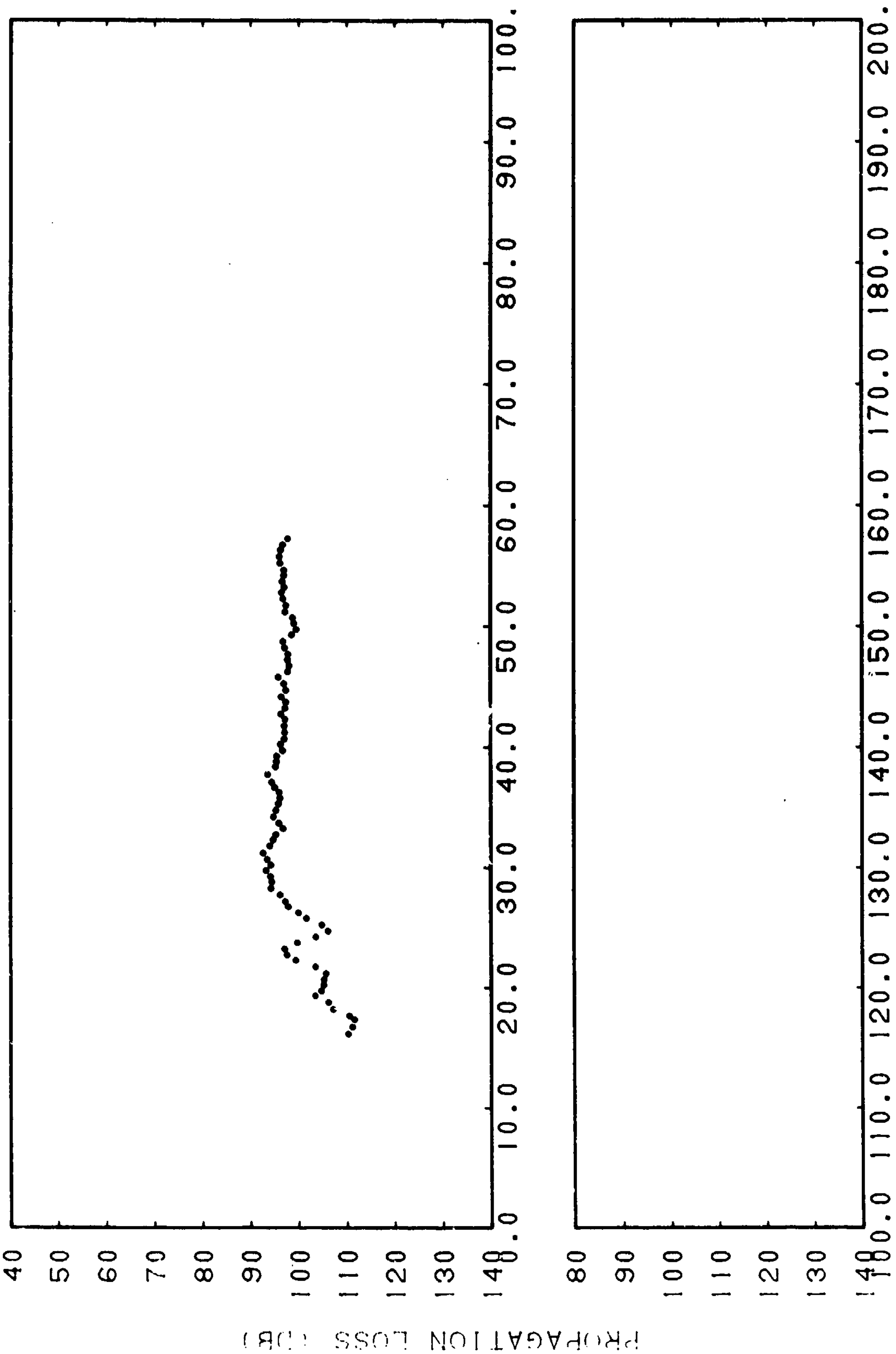
(C) Figure IIIH-33. Smoothed Gulf of Alaska, Run 112B, Source Depth = 305 Meters, Receiver Depth = 305 Meters, Frequency = 2.5 Kilohertz



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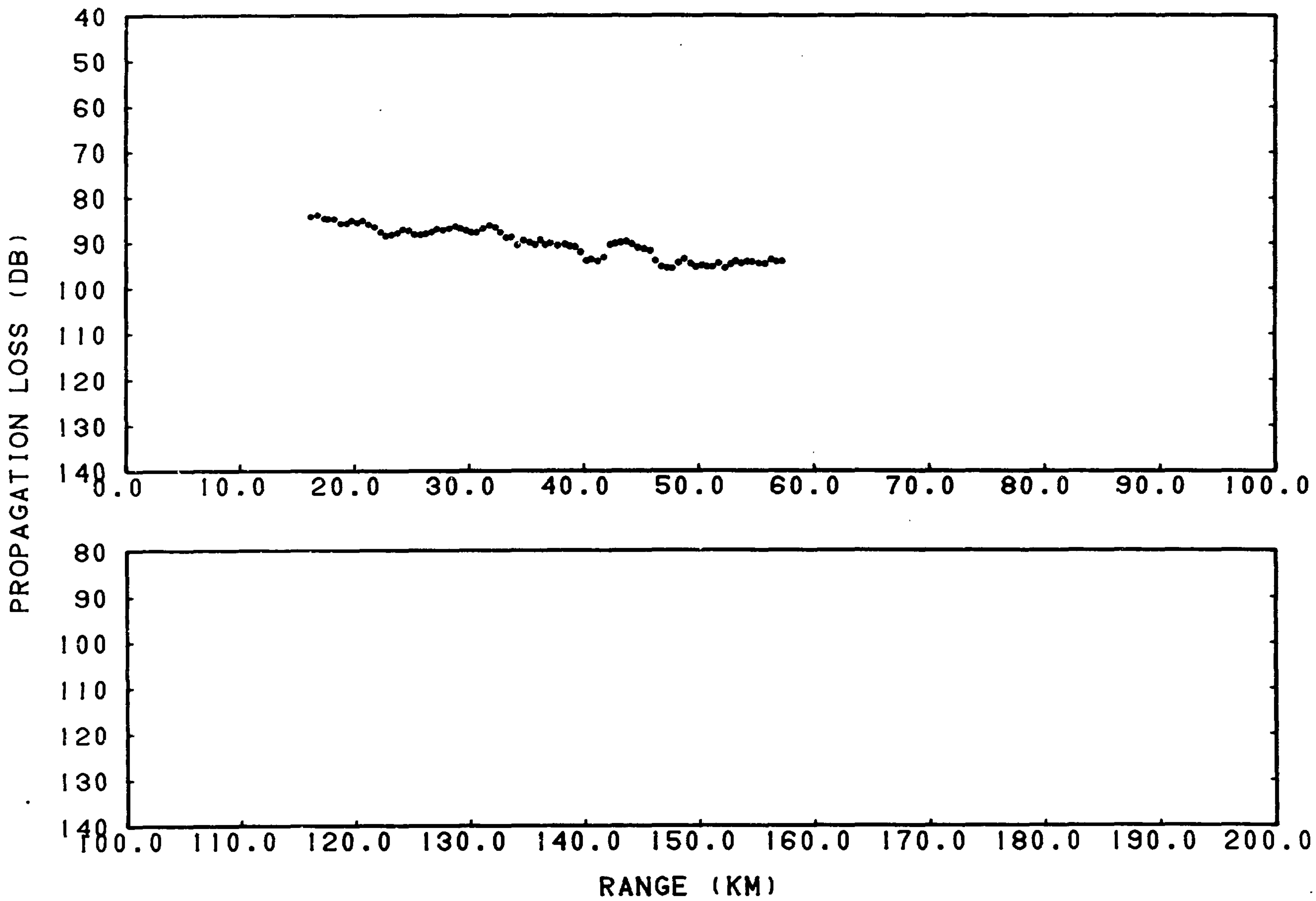
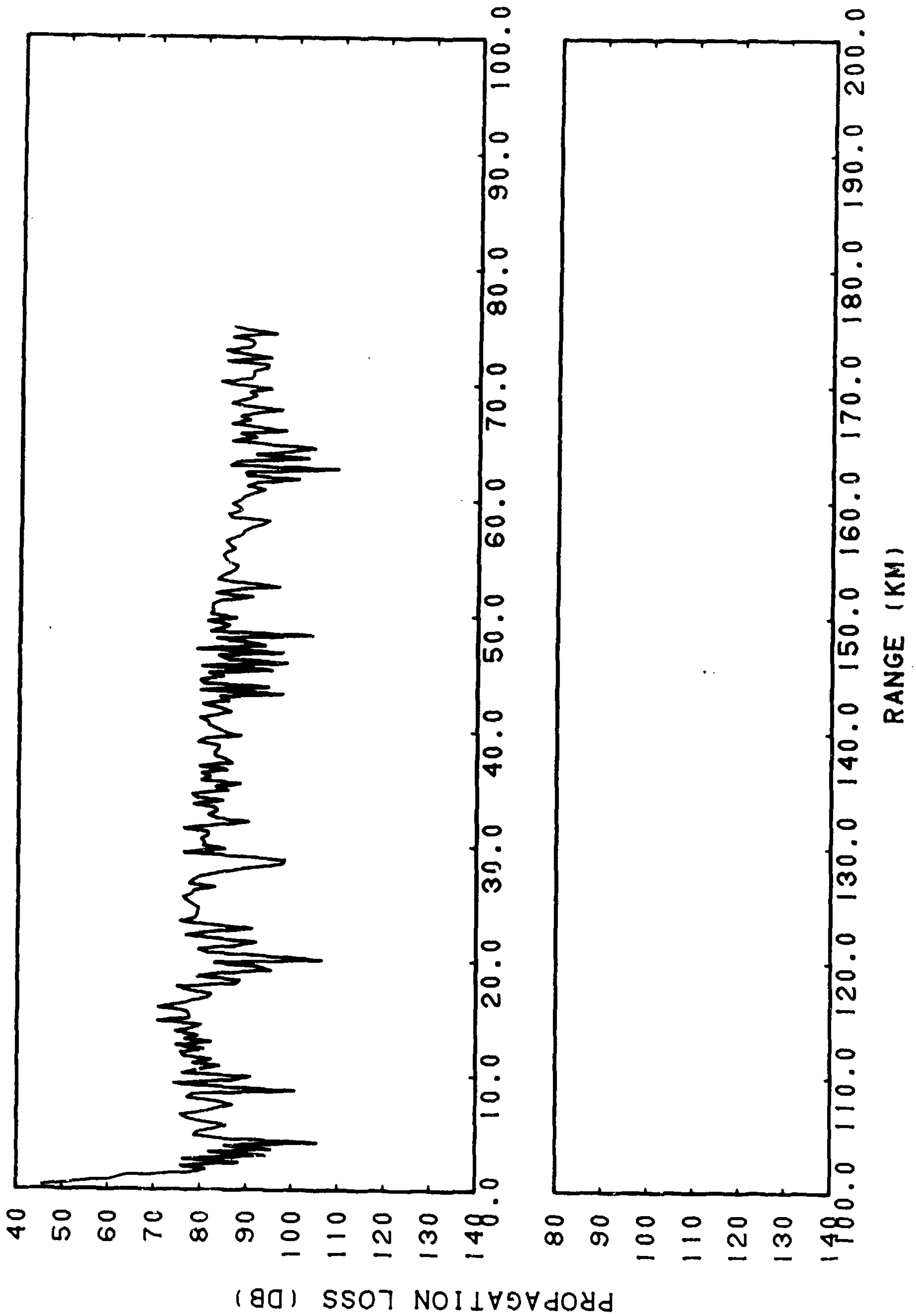
(C) Figure IIIH-34. Smoothed Gulf of Alaska, Run 112A, Source Depth = 305 Meters, Receiver Depth = 30.5 Meters, Frequency = 2.5 Kilohertz



CONFIDENTIAL

(C) Figure IIIH-35. Smoothed Gulf of Alaska, Run 112A, Source Depth = 305 Meters, Receiver Depth = 305 Meters, Frequency = 2.5 Kilohertz



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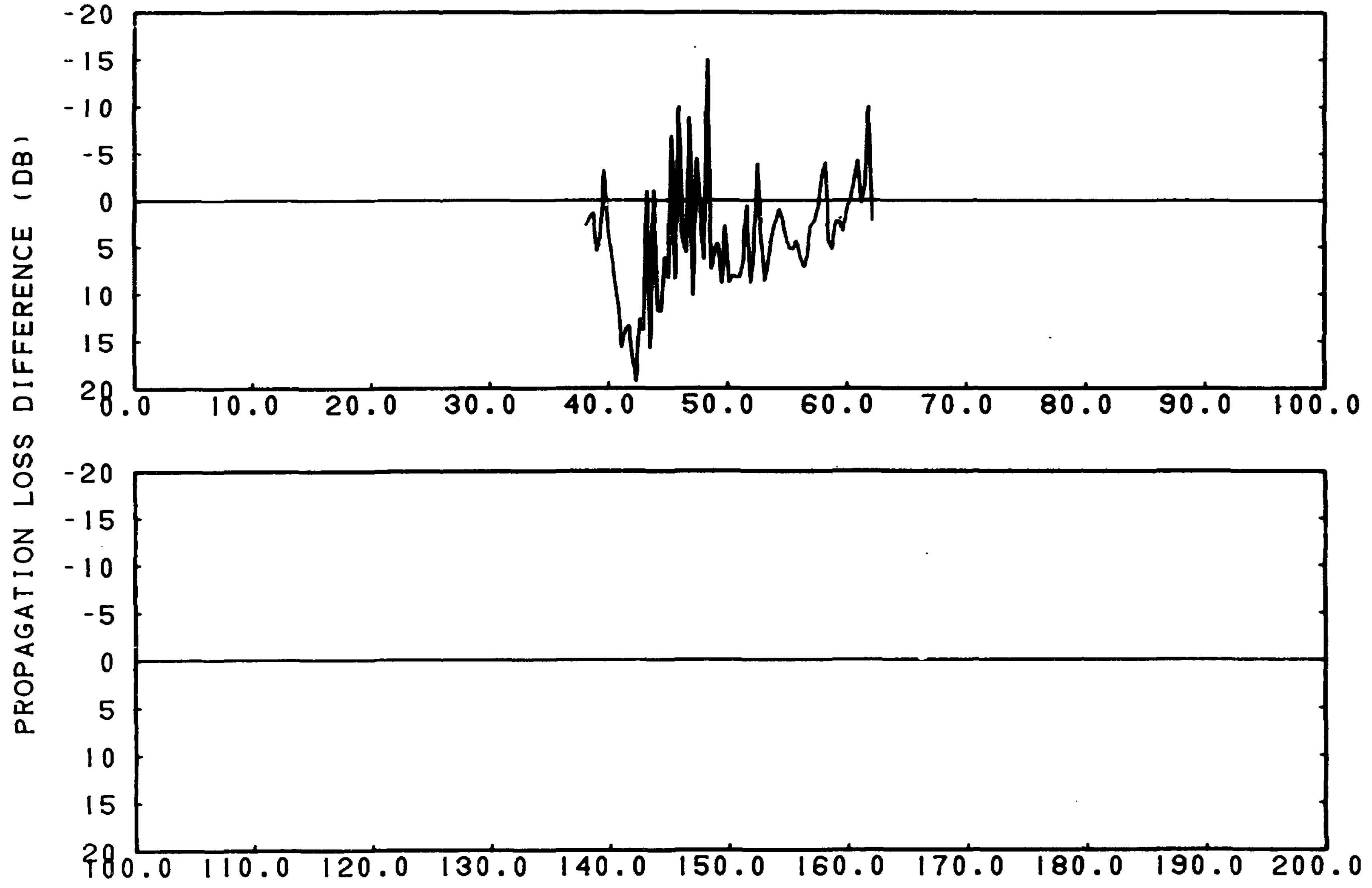
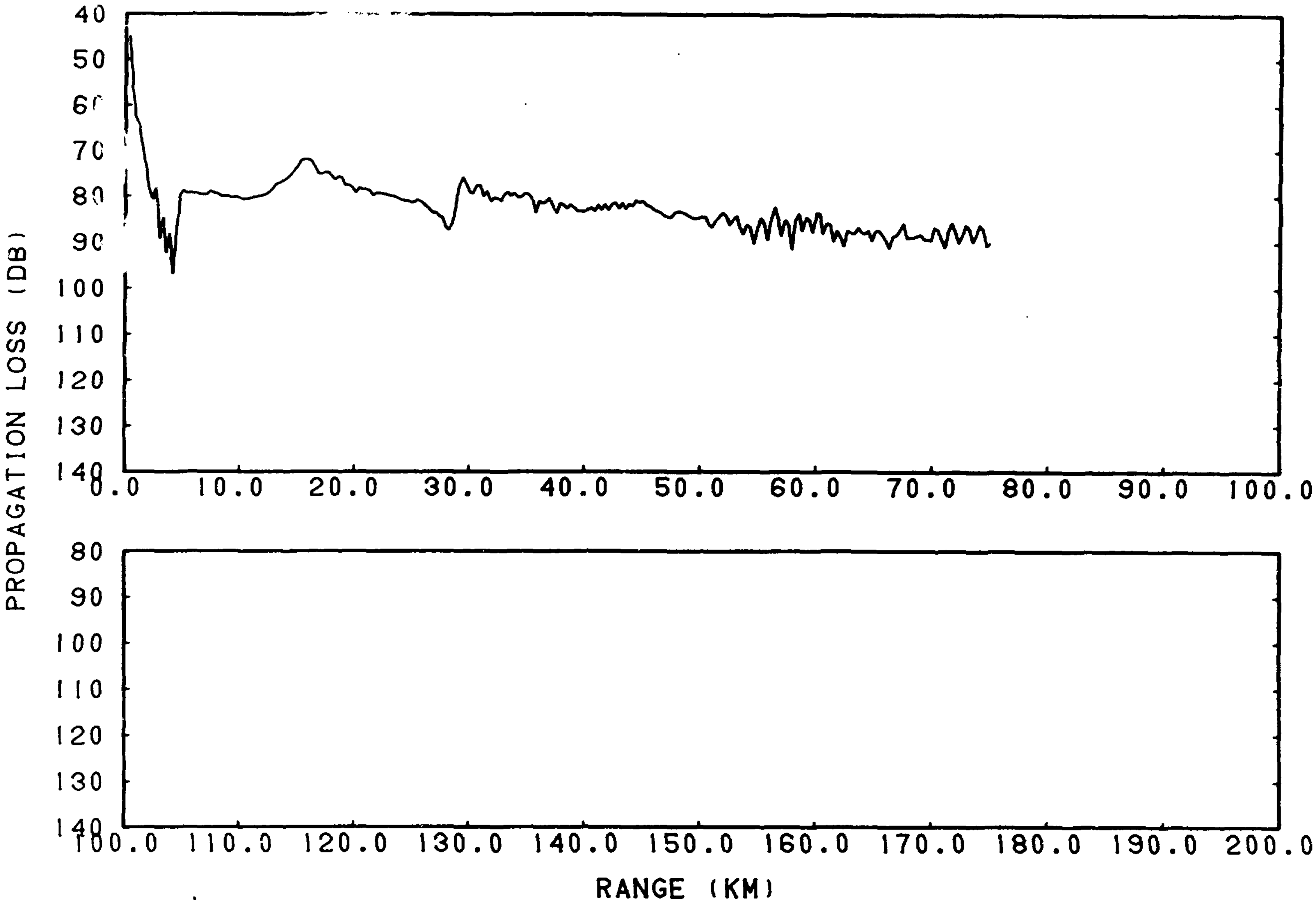
(C) Figure IIIH-36. RAYMODE Coherent, Run 140, Source Depth = 30.5 Meters, Receiver Depth = 30.5 Meters, Frequency = 1.5 Kilohertz



CONFIDENTIAL

(C) Figure IIIH-37. RAYMODE Coherent, Run 140, Source Depth = 30.5 Meters, Receiver Depth = 30.5 Meters, Frequency = 1.5 Kilohertz, Subtracted from Smoothed Gulf of Alaska, Run 140, Source Depth = 30.5 Meters, Receiver Depth = 30.5 Meters, Frequency = 1.5 Kilohertz



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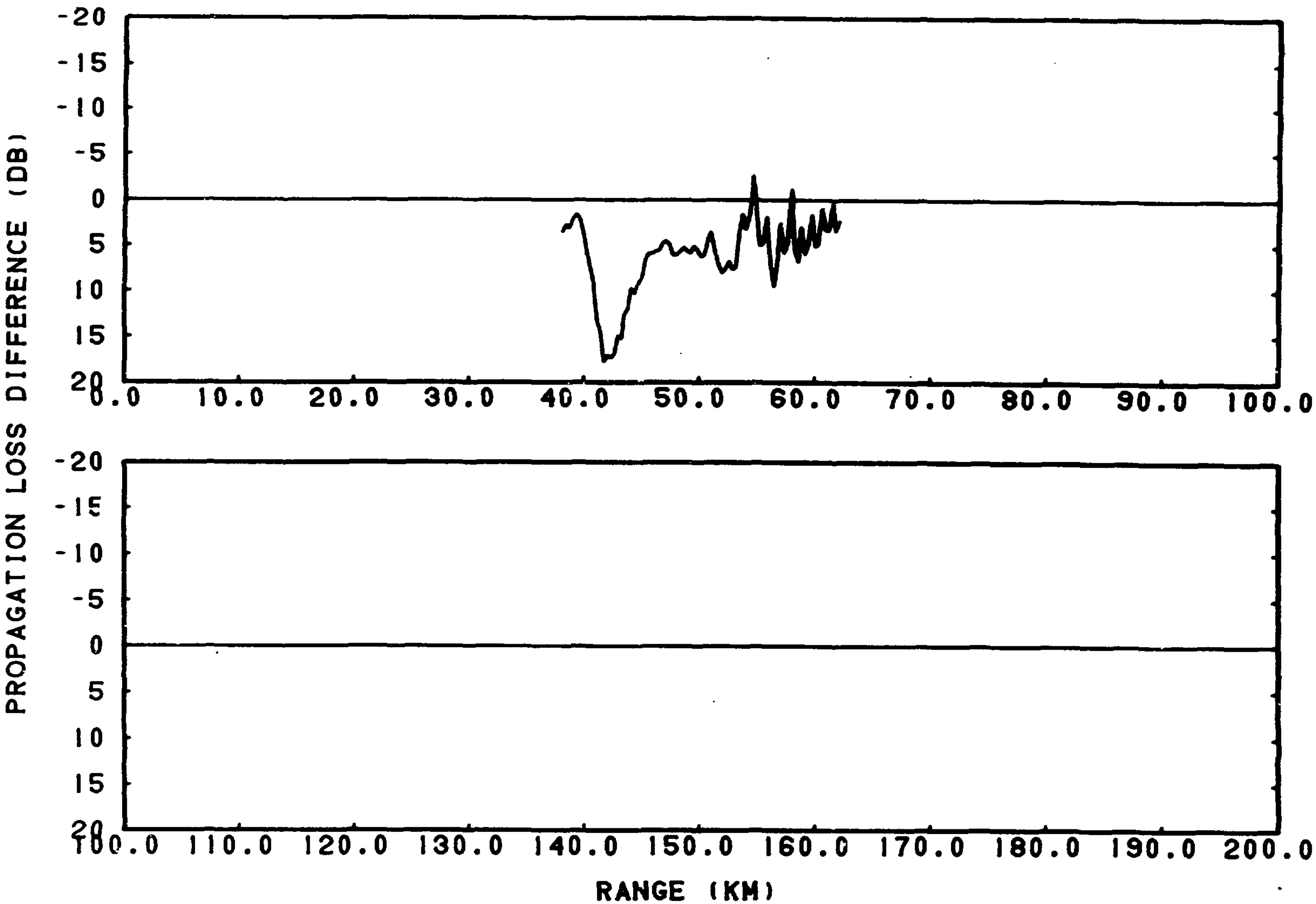
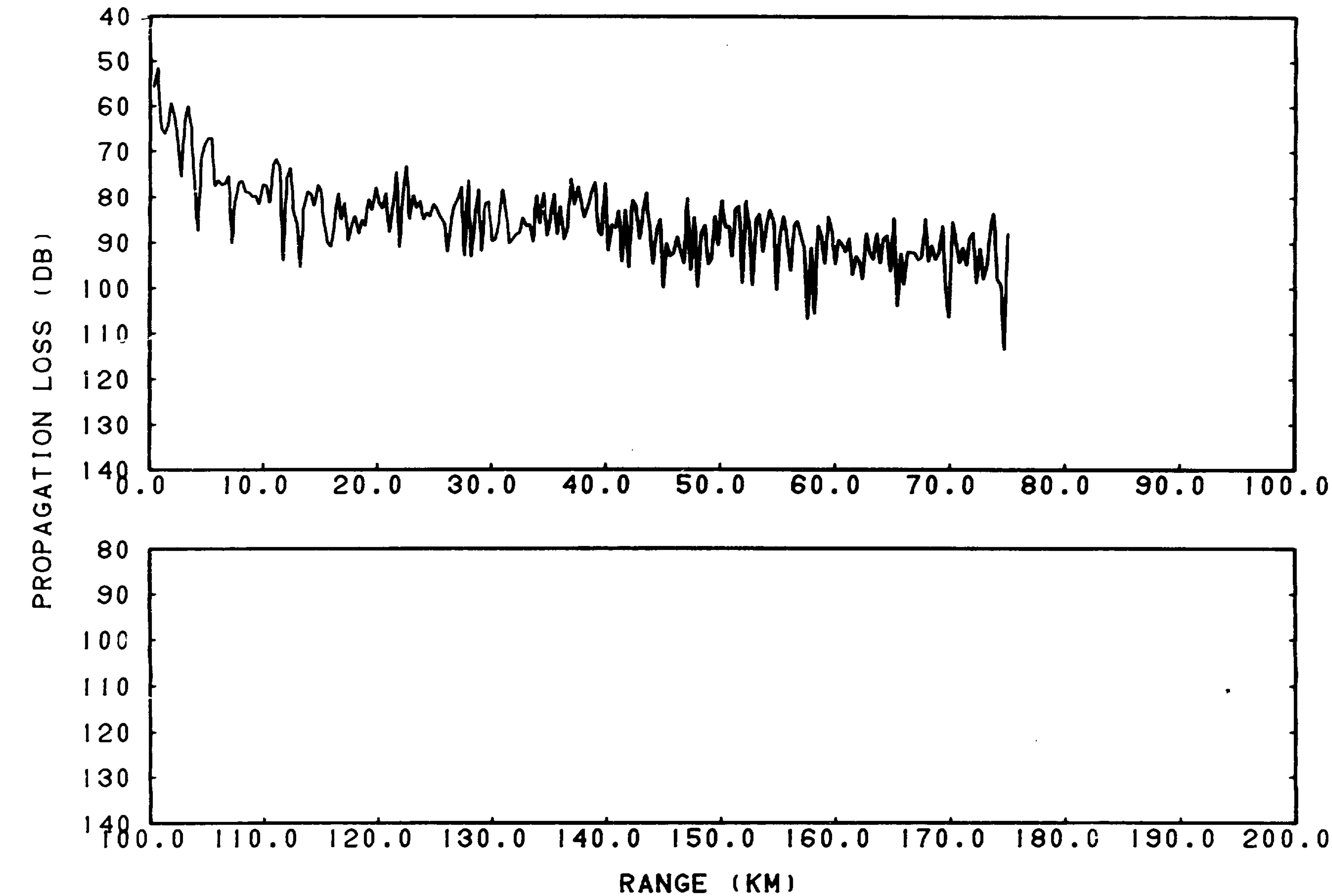
(C) Figure IIIH-38. RAYMODE Incoherent, Run 140, Source Depth = 30.5 Meters, Receiver Depth = 30.5 Meters, Frequency = 1.5 Kilohertz



CONFIDENTIAL

(C) Figure IIIH-39. RAYMODE Incoherent, Run 140, Source Depth = 30.5 Meters, Receiver Depth = 30.5 Meters, Frequency = 1.5 Kilohertz, Subtracted from Smoothed Gulf of Alaska, Run 140, Source Depth = 30.5 Meters, Receiver Depth = 30.5, Frequency = 1.5 Kilohertz



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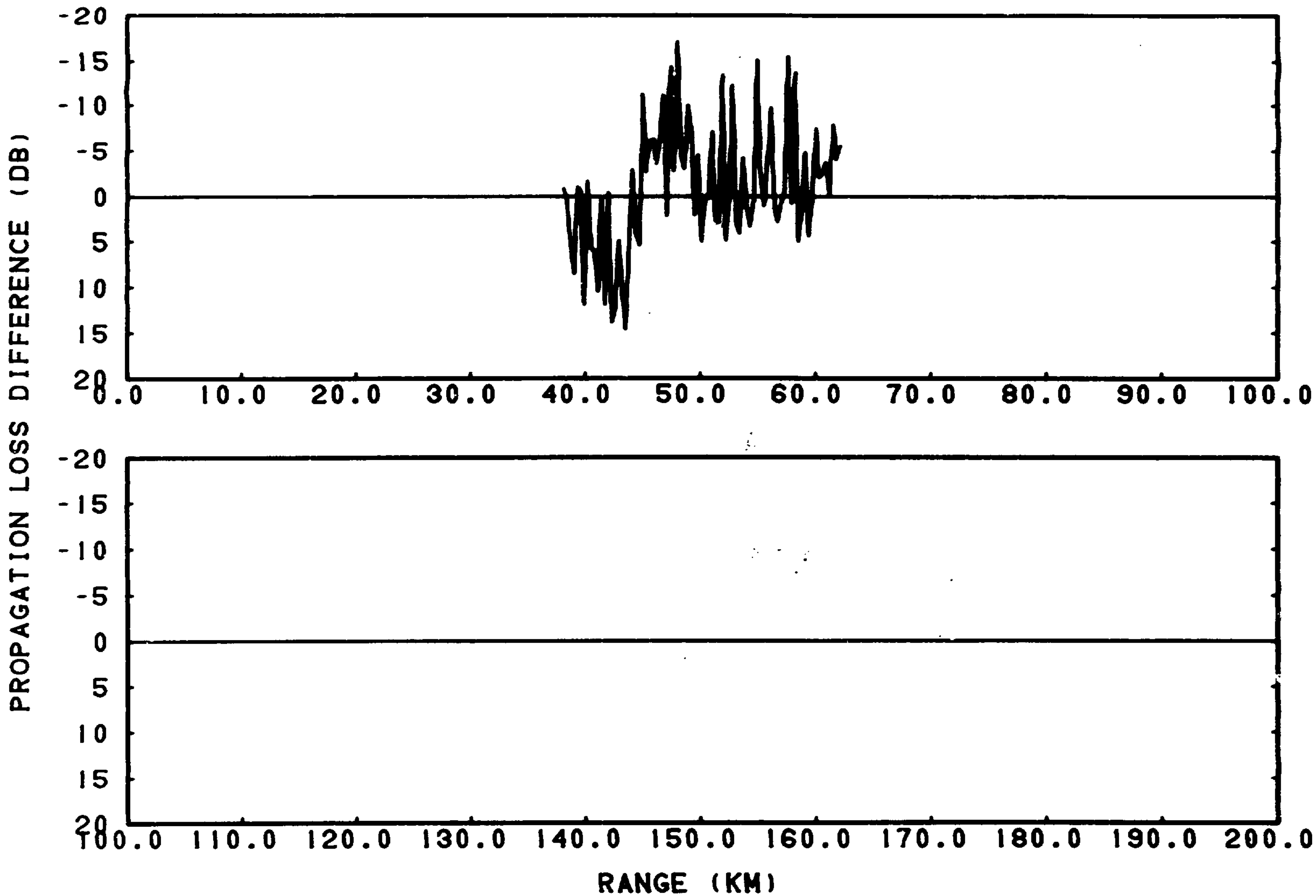
(C) Figure IIIH-40. RAYMODE Coherent, Run 140, Source Depth = 30.5 Meters, Receiver Depth = 305 Meters, Frequency = 1.5 Kilohertz



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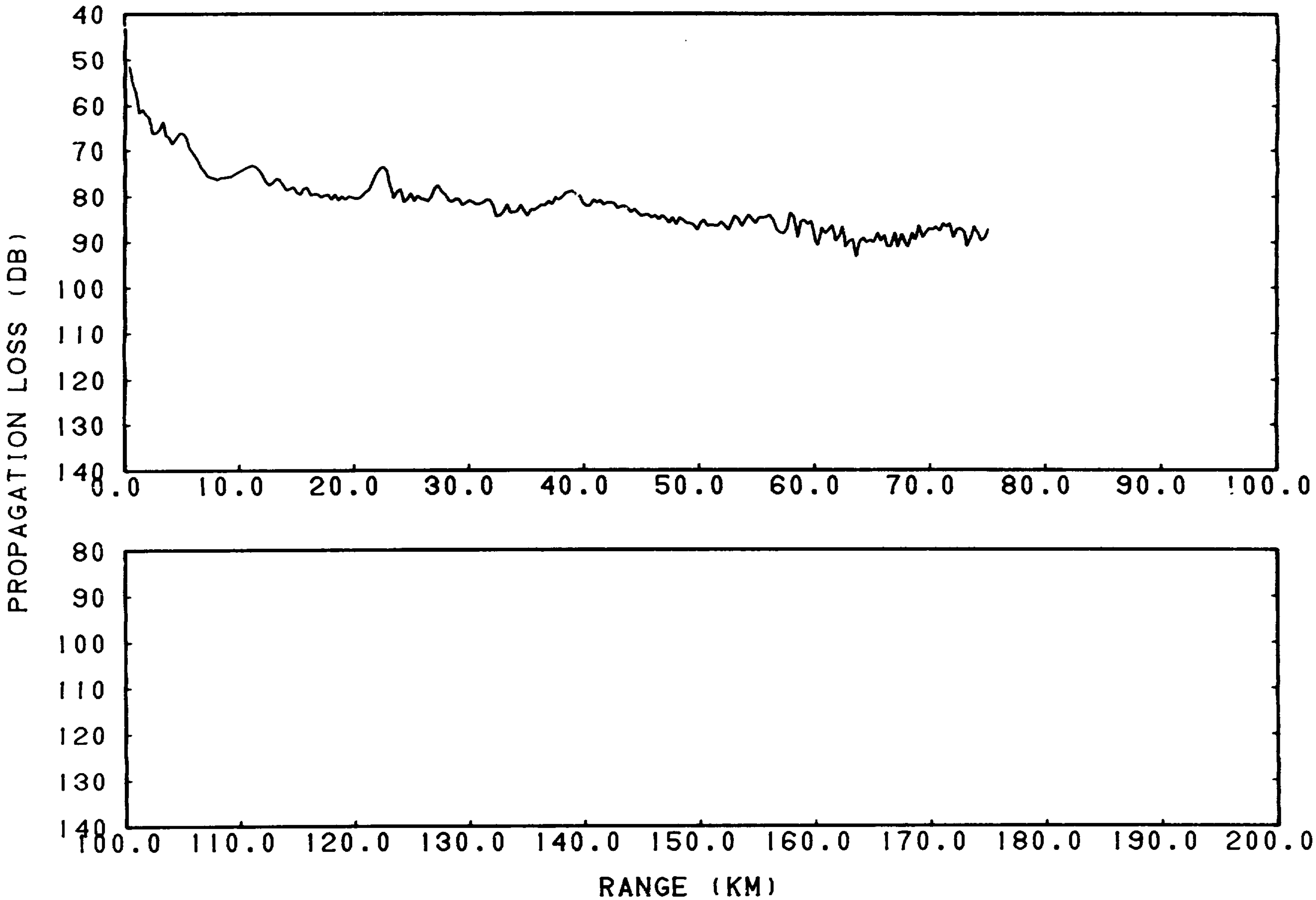
(C) Figure IIIH-41. RAYMODE Coherent, Run 140, Source Depth = 30.5 Meters, Receiver Depth = 305 Meters, Frequency = 1.5 Kilohertz, Subtracted from Smoothed Gulf of Alaska, Run 140, Source Depth = 30.5 Meters, Receiver Depth = 305 Meters, Frequency = 1.5 Kilohertz



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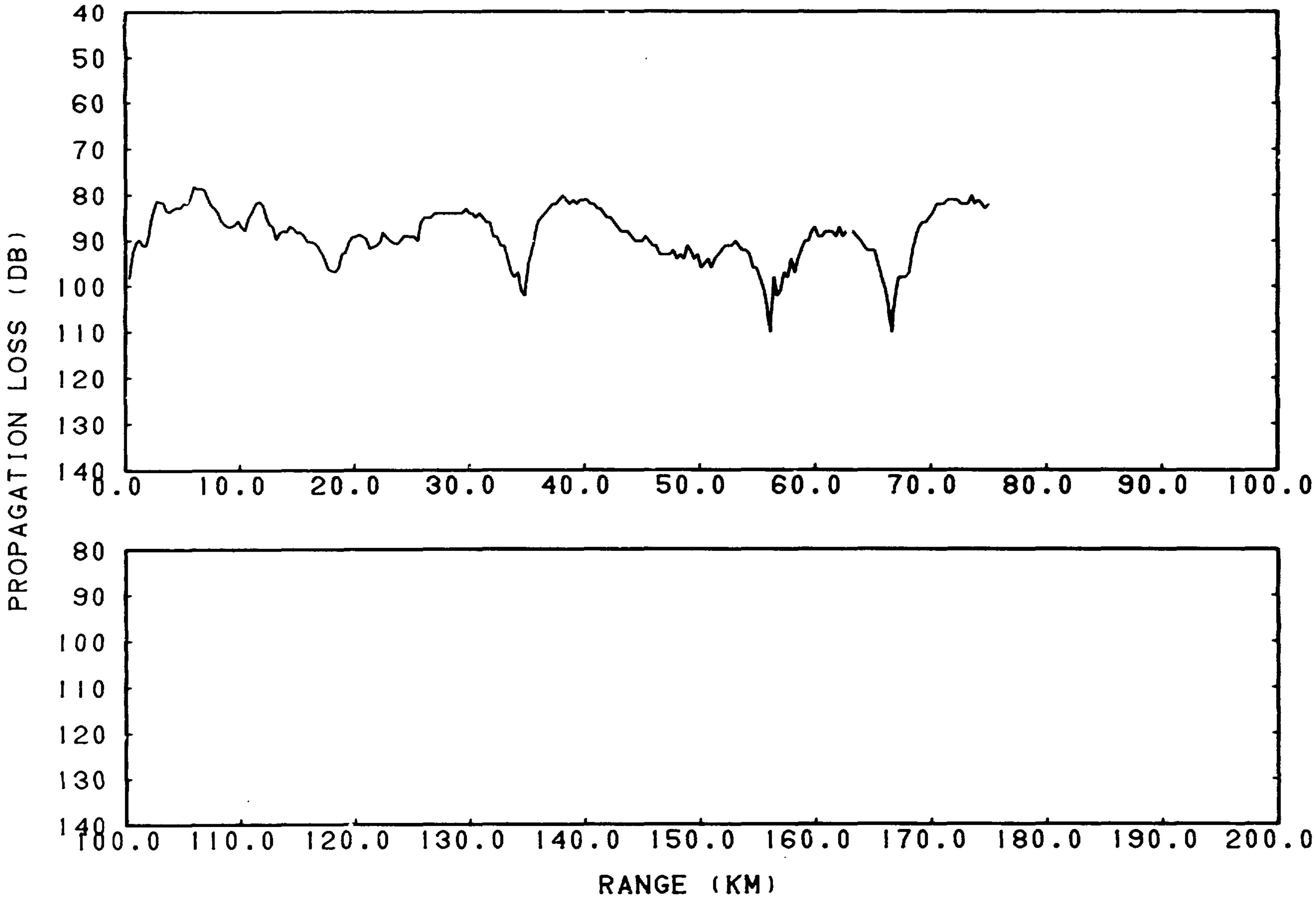
(C) Figure IIIH-42. RAYMODE Incoherent, Run 140, Source Depth = 30.5 Meters, Receiver Depth = 305 Meters, Frequency = 1.5 Kilohertz



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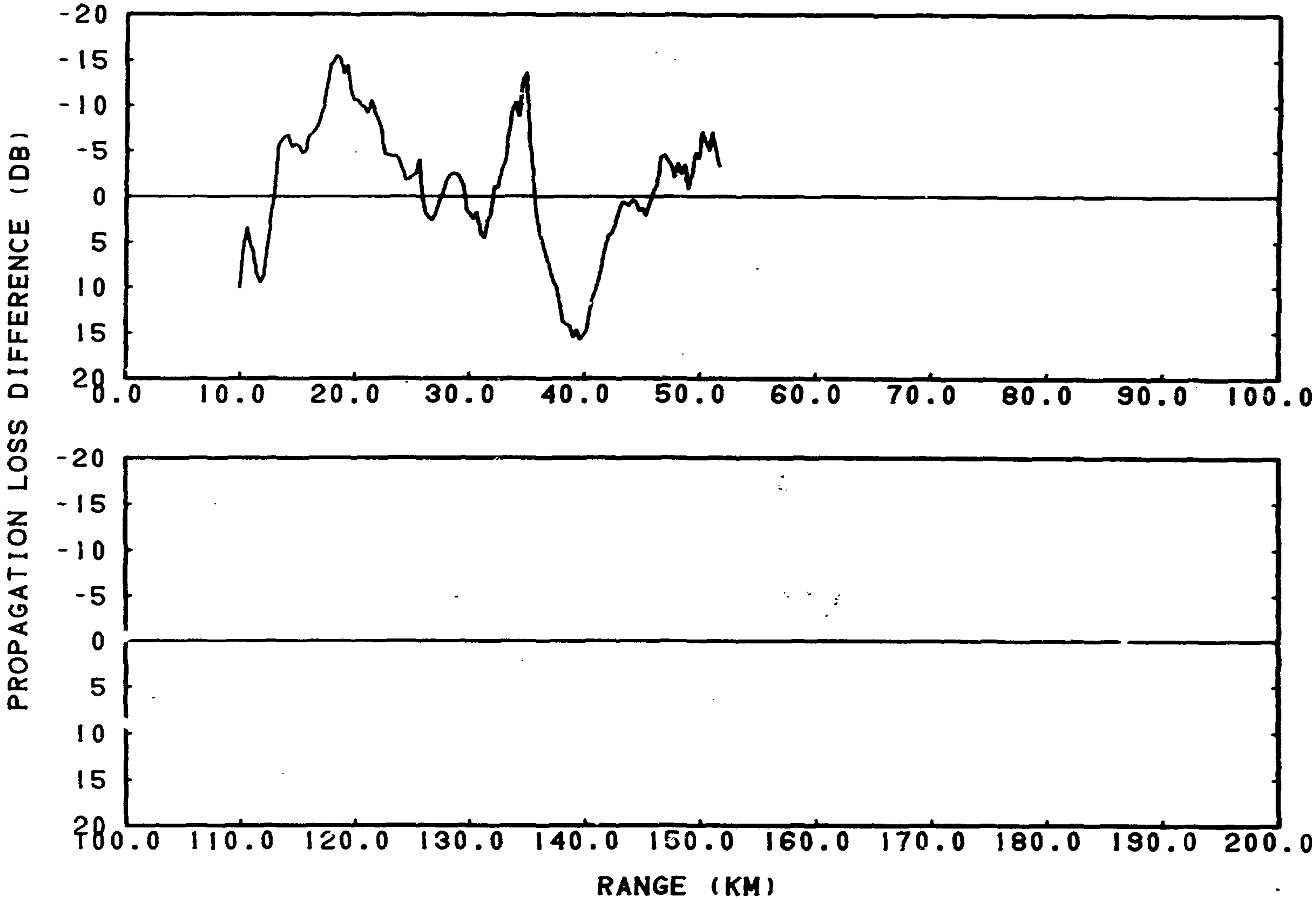
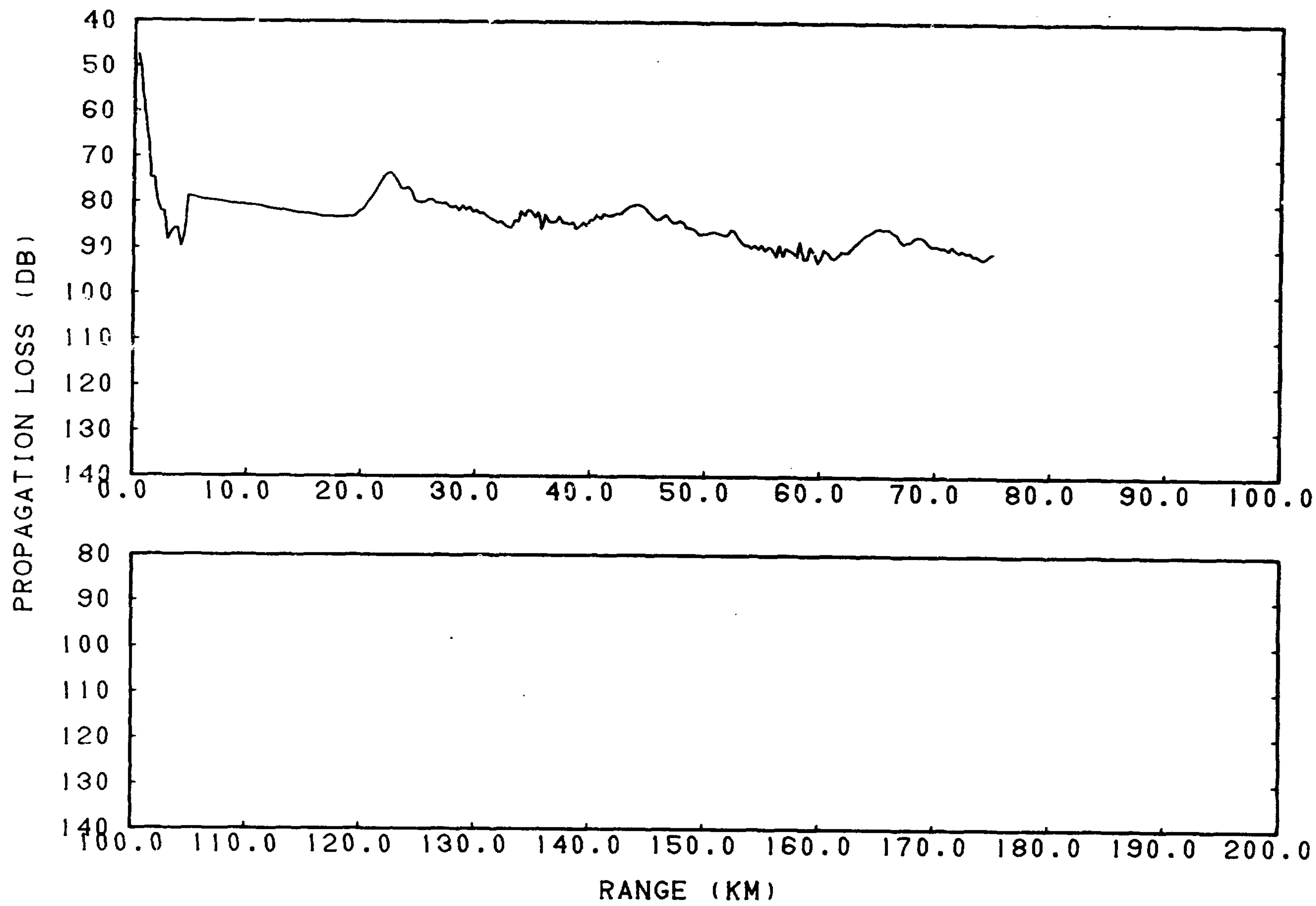
(C) Figure IIIH-43. RAYMODE Coherent, Run 143, Source Depth = 30.5 Meters, Receiver Depth = 30.5 Meters, Frequency = 1.5 Kilohertz



CONFIDENTIAL

(C) Figure IIIH-44. RAYMODE Coherent, Run 143, Source Depth = 30.5 Meters, Receiver Depth = 30.5 Meters, Frequency = 1.5 Kilohertz, Subtracted from Smoothed Gulf of Alaska, Run 143, Source Depth = 30.5 Meters, Receiver Depth = 30.5 Meters, Frequency = 1.5 Kilohertz



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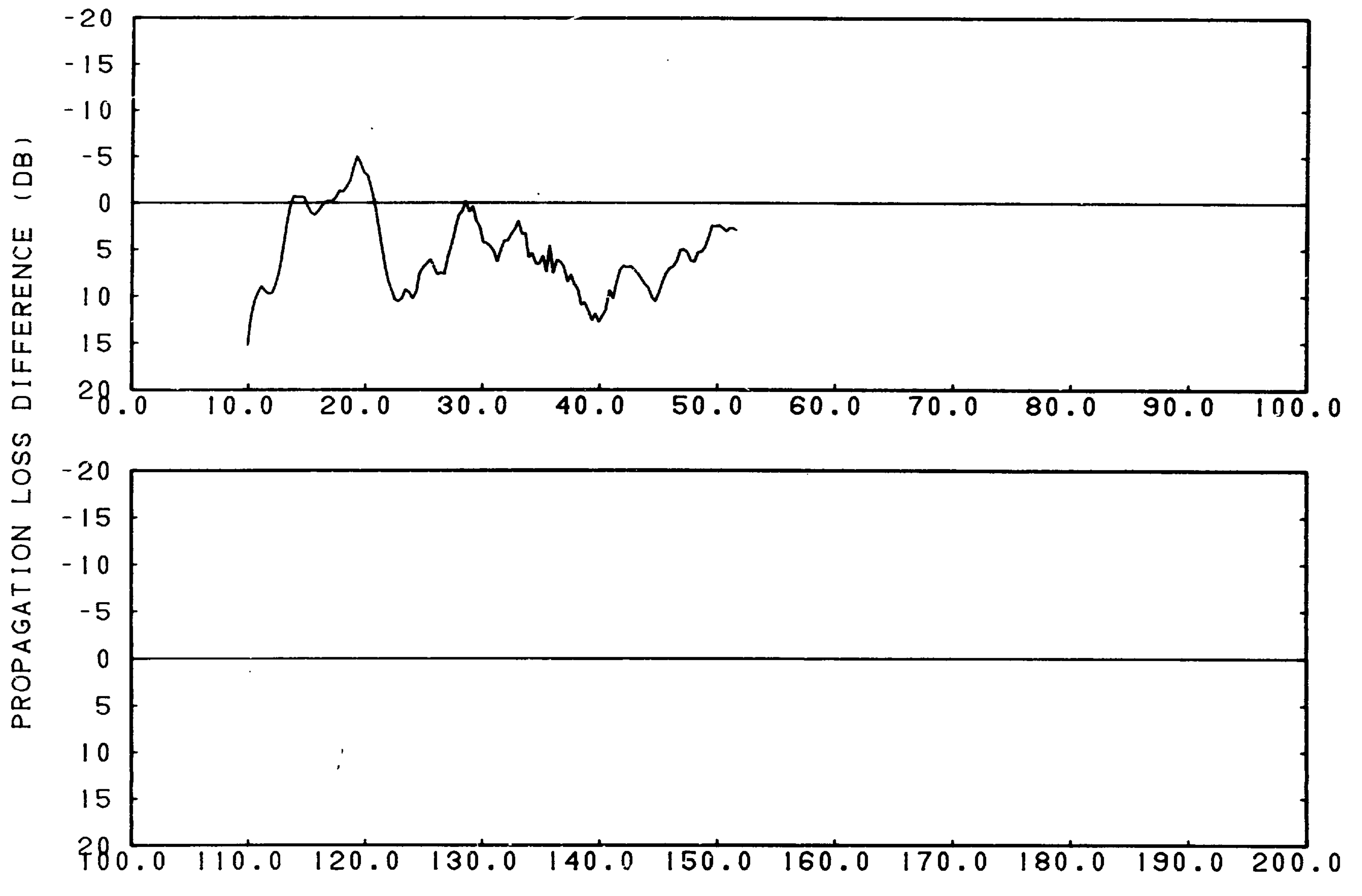
(C) Figure IIIH-45. RAYMODE Incoherent, Run 143, Source Depth = 30.5 Meters, Receiver Depth = 30.5 Meters, Frequency = 1.5 Kilohertz



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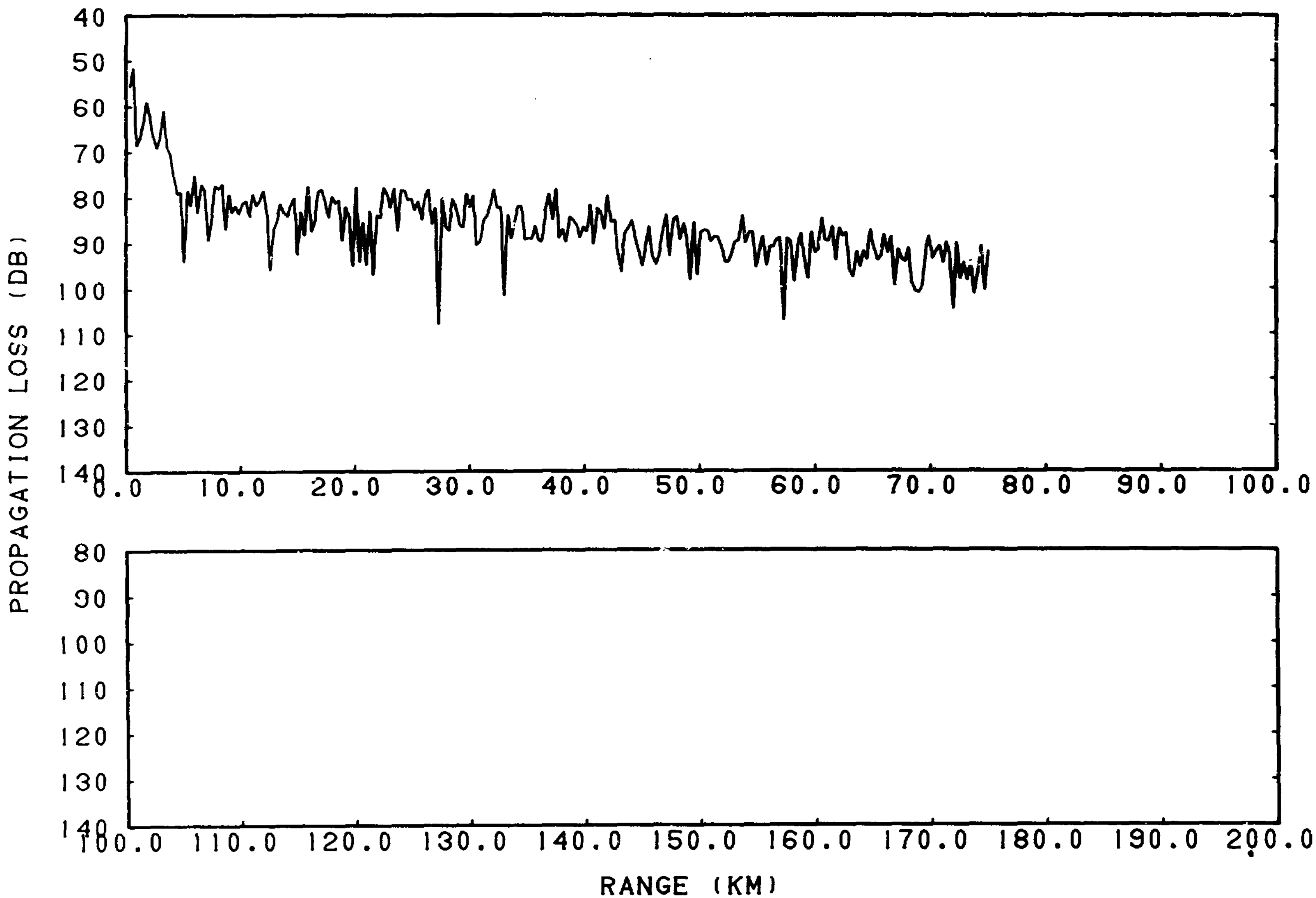
(C) Figure IIIH-46. RAYMODE Incoherent, Run 143, Source Depth = 30.5 Meters, Receiver Depth = 30.5 Meters, Frequency = 1.5 Kilohertz, Subtracted from Smoothed Gulf of Alaska, Run 143, Source Depth = 30.5 Meters, Receiver Depth = 30.5 Meters, Frequency = 1.5 Kilohertz



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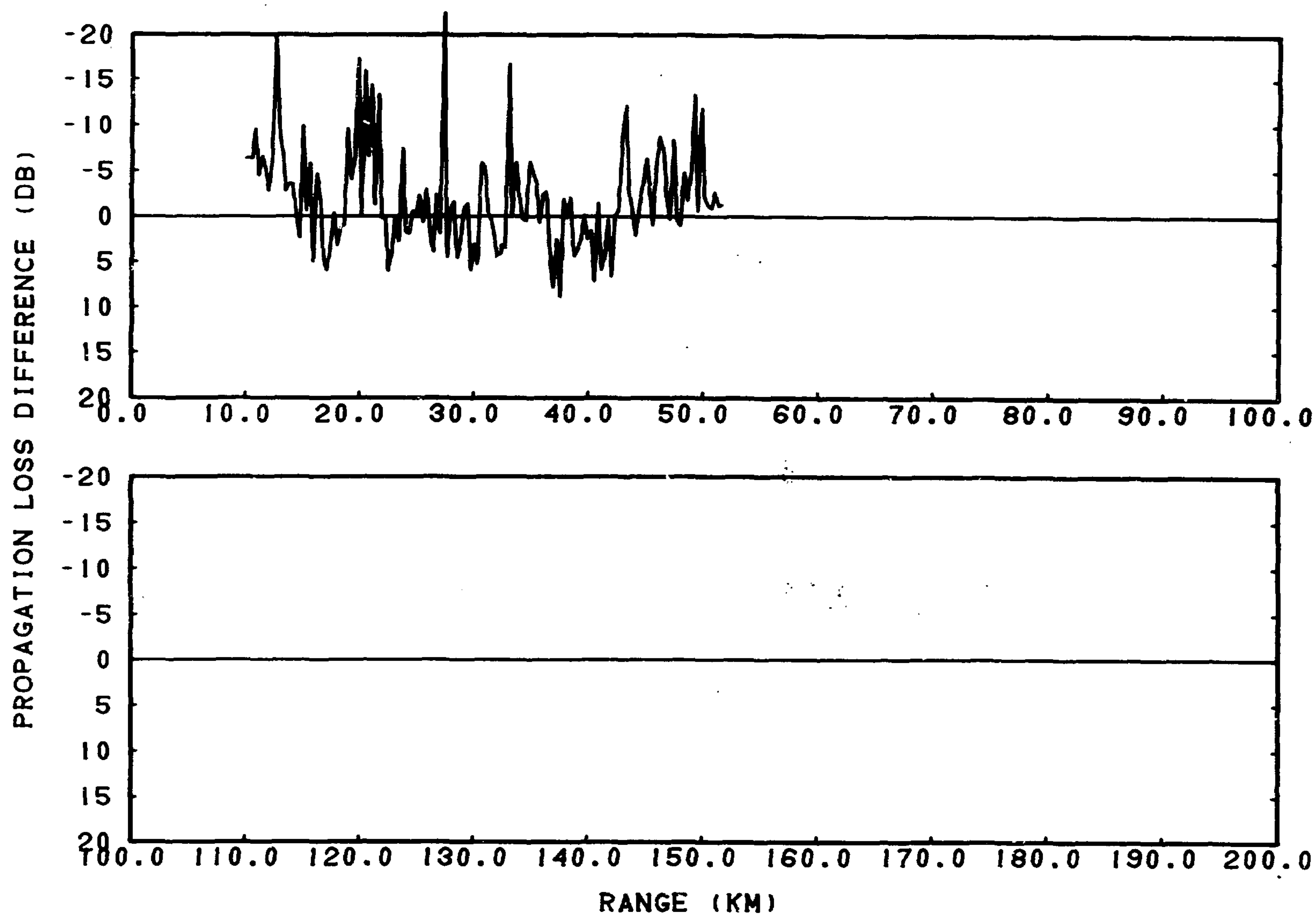
(C) Figure IIIH-47. RAYMODE Coherent, Run 143, Source Depth = 30.5 Meters, Receiver Depth = 305 Meters, Frequency = 1.5 Kilohertz



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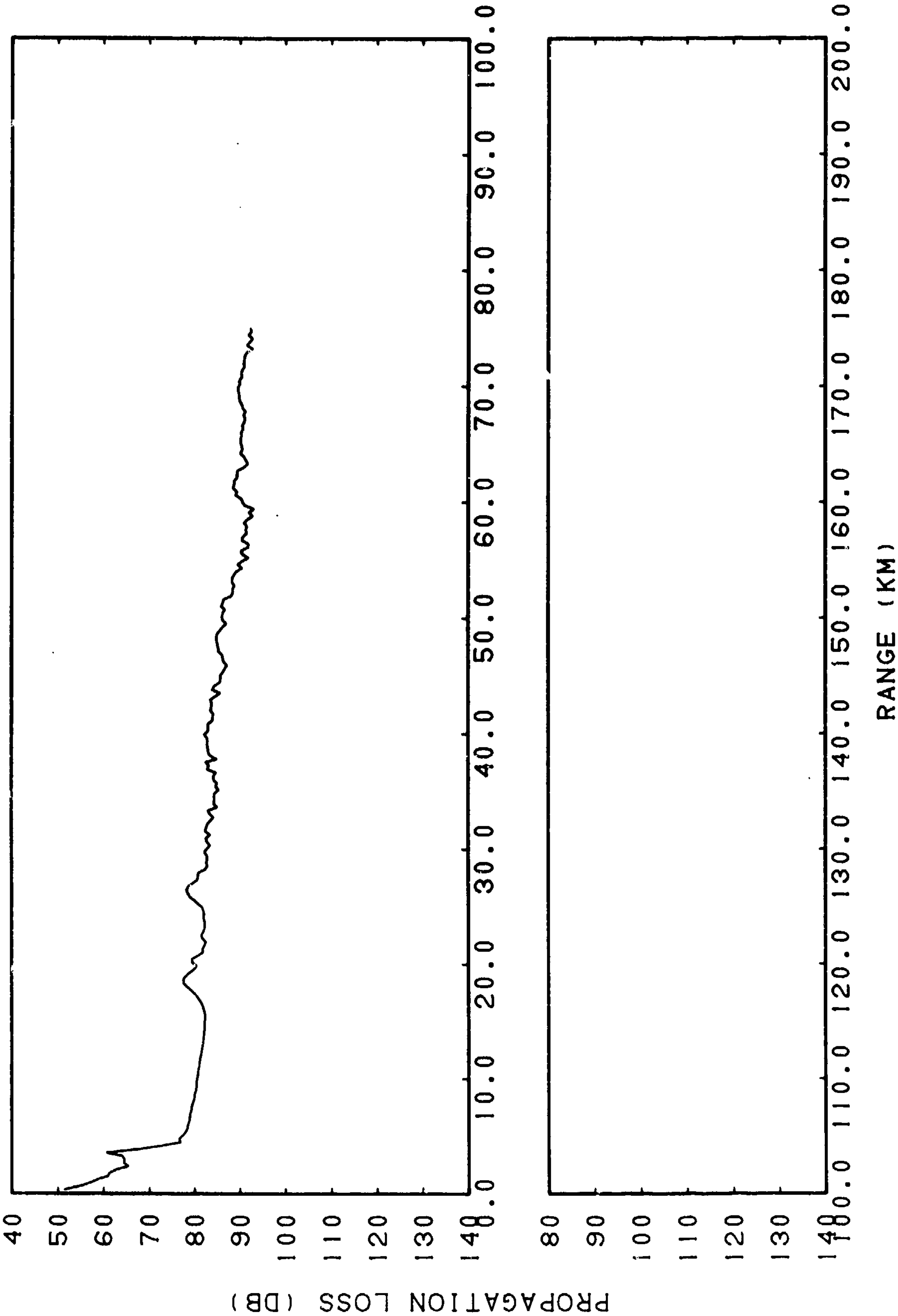
(C) Figure IIIH-48. RAYMODE Coherent, Run 143, Source Depth = 30.5 Meters, Receiver Depth = 305 Meters, Frequency = 1.5 Kilohertz, Subtracted from Smoothed Gulf of Alaska, Run 143, Source Depth = 30.5 Meters, Receiver Depth = 305 Meters, Frequency = 1.5 Kilohertz



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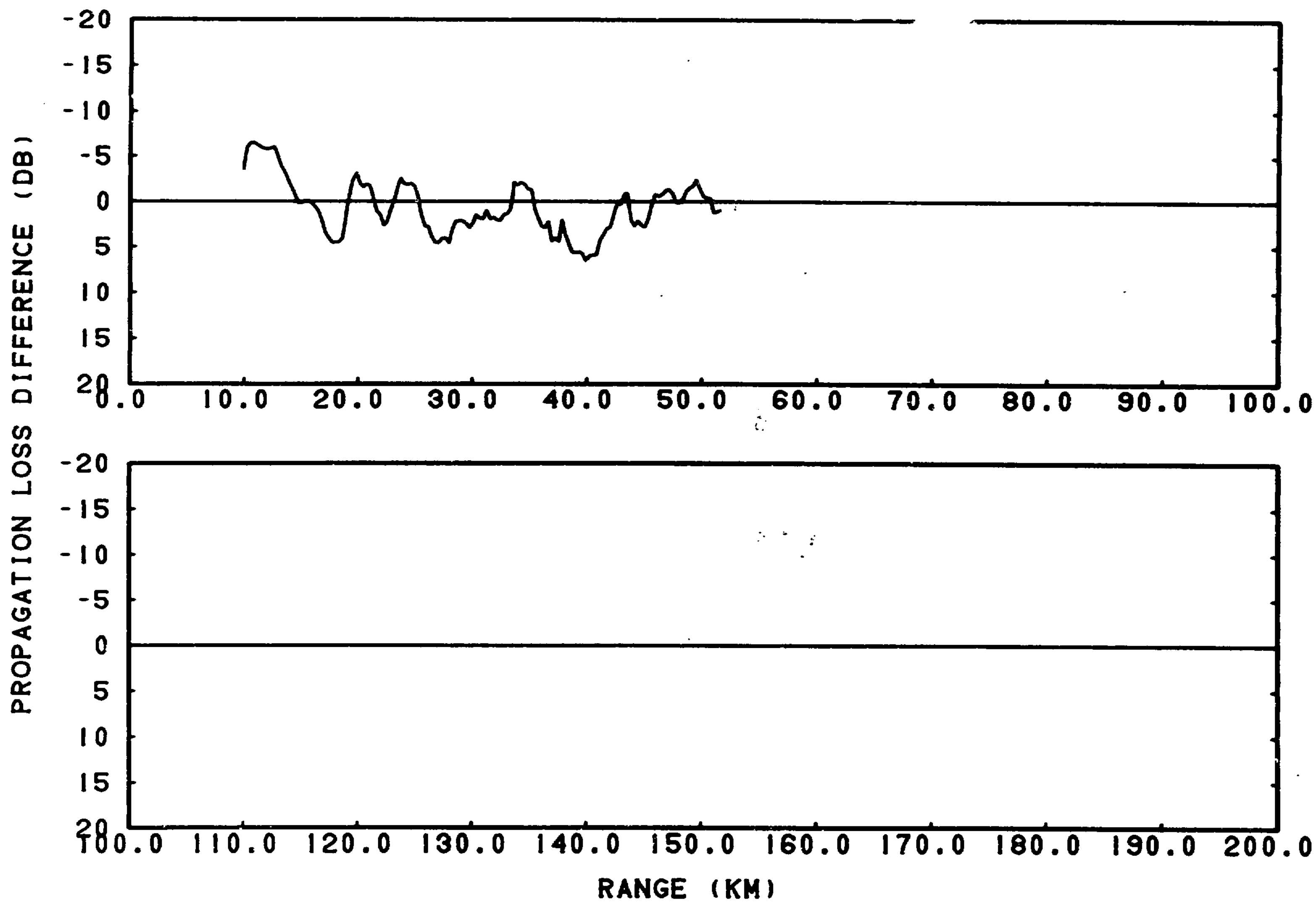
(C) Figure IIIH-49. RAYMODE Incoherent, Run 143, Source Depth = 30.5 Meters, Receiver Depth = 305 Meters, Frequency = 1.5 Kilohertz



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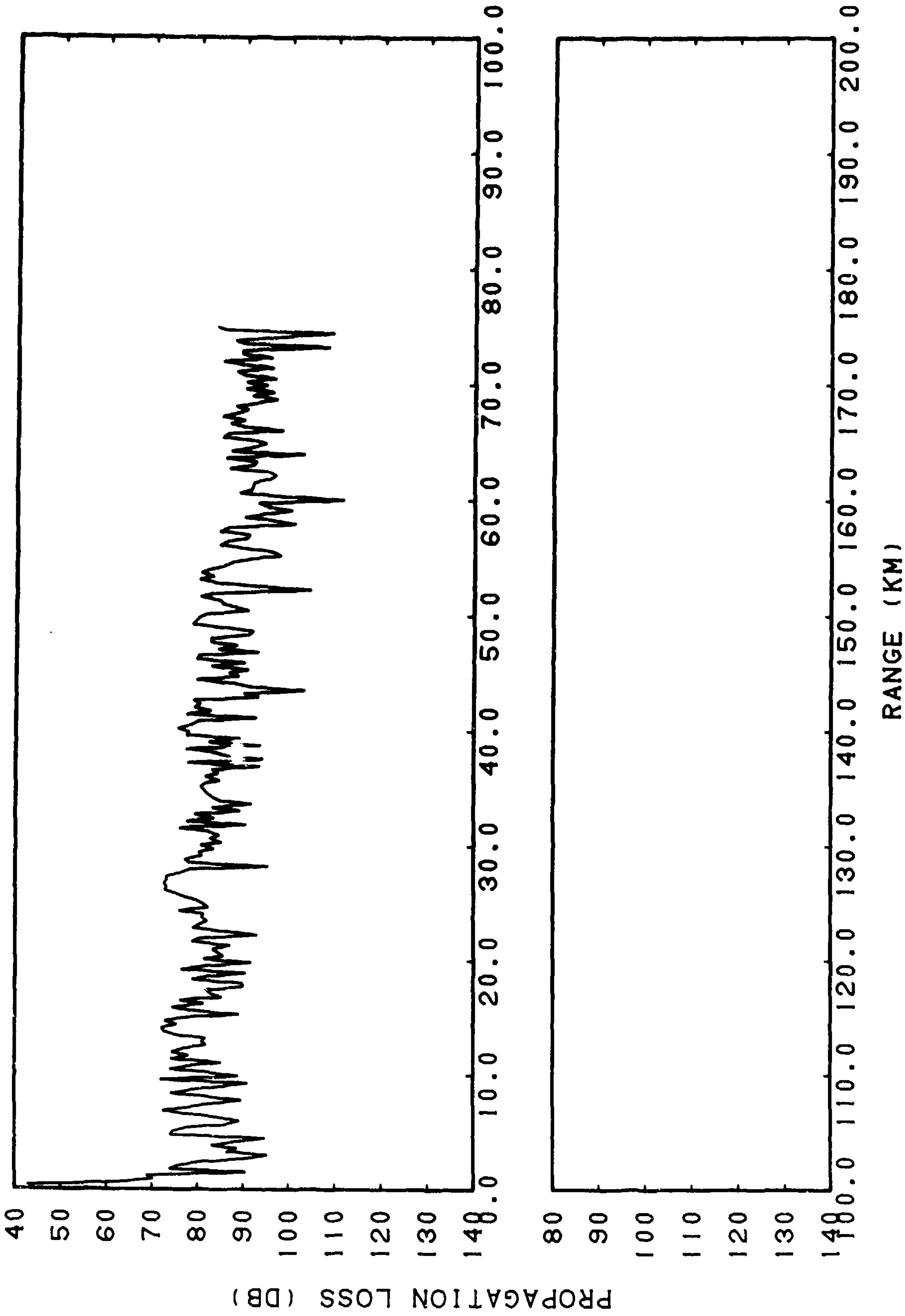
(C) Figure IIIH-50. RAYMODE Incoherent, Run 143, Source Depth = 30.5 Meters, Receiver Depth = 305 Meters, Frequency = 1.5 Kilohertz, Subtracted from Smoothed Gulf of Alaska, Run 143, Source Depth = 30.5, Receiver Depth = 305 Meters, Frequency = 1.5 Kilohertz



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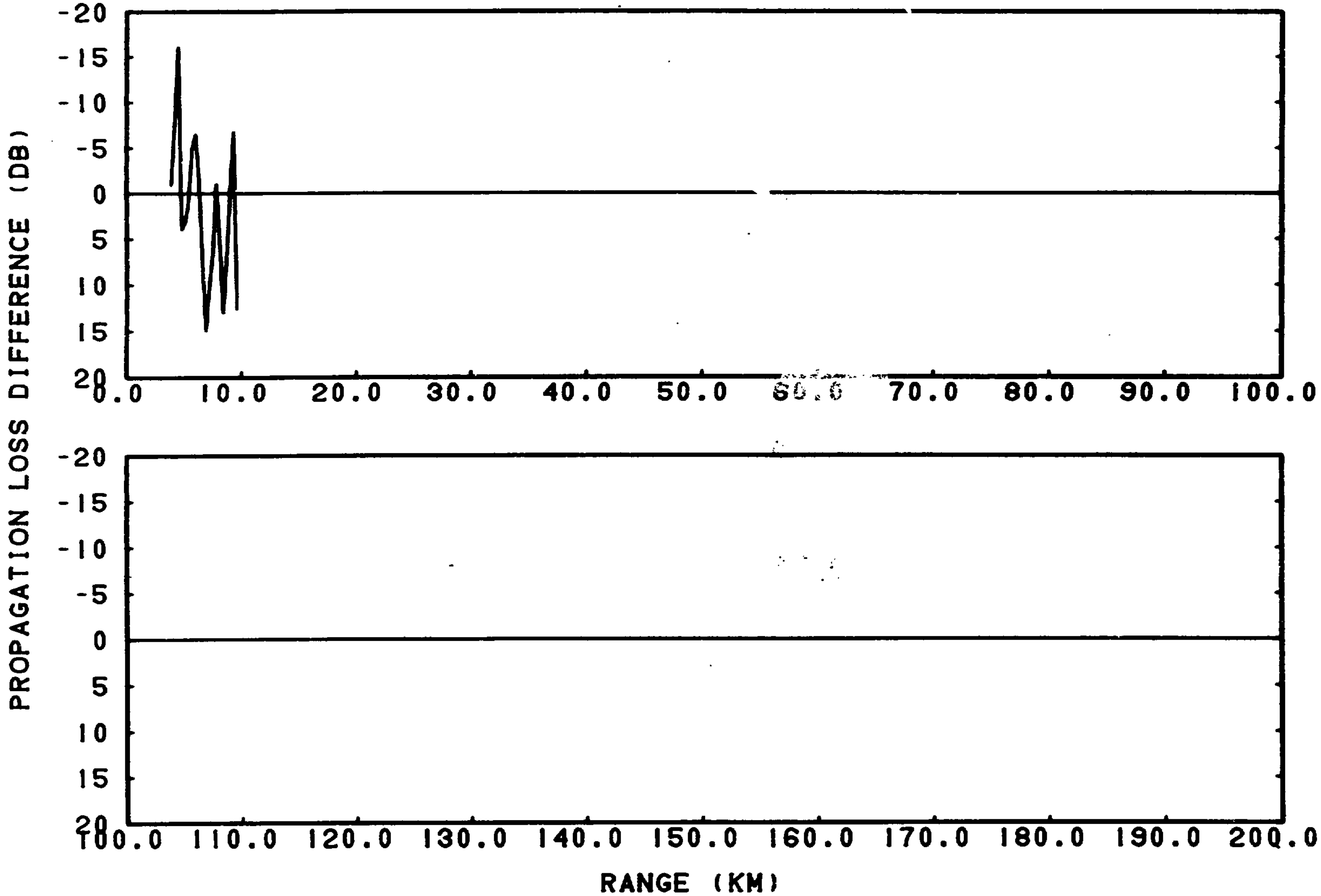
(C) Figure IIIH-51. RAYMODE Coherent, Run 124, Source Depth = 30.5 Meters, Receiver Depth = 30.5 Meters, Frequency = 1.5 Kilohertz



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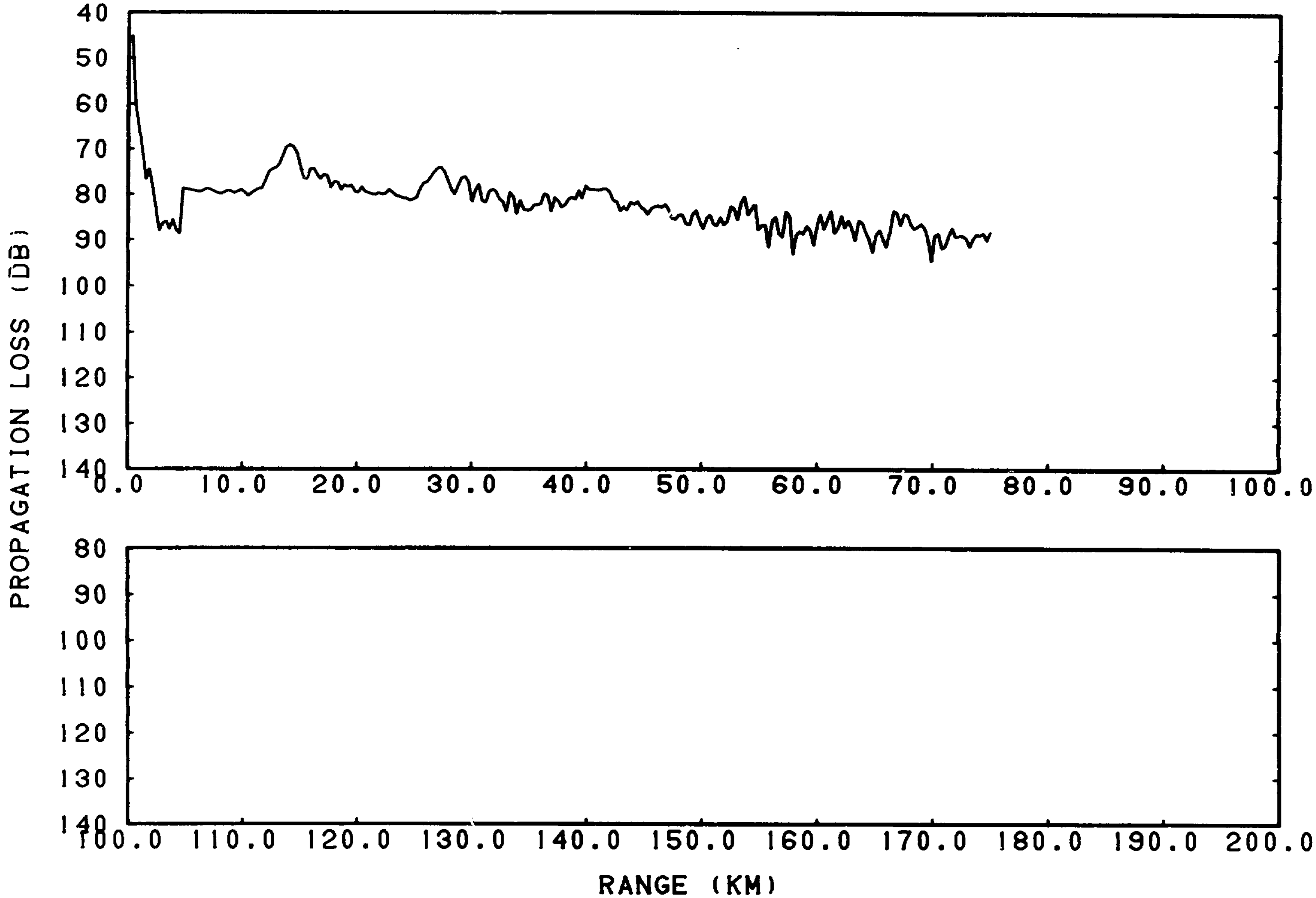
(C) Figure IIIH-52. RAYMODE Coherent, Run 124, Source Depth = 30.5 Meters, Receiver Depth = 30.5 Meters, Frequency = 1.5 Kilohertz, Subtracted from Smoothed Gulf of Alaska, Run 124, Source Depth = 30.5 Meters, Receiver Depth = 30.5 Meters, Frequency = 1.5 Kilohertz



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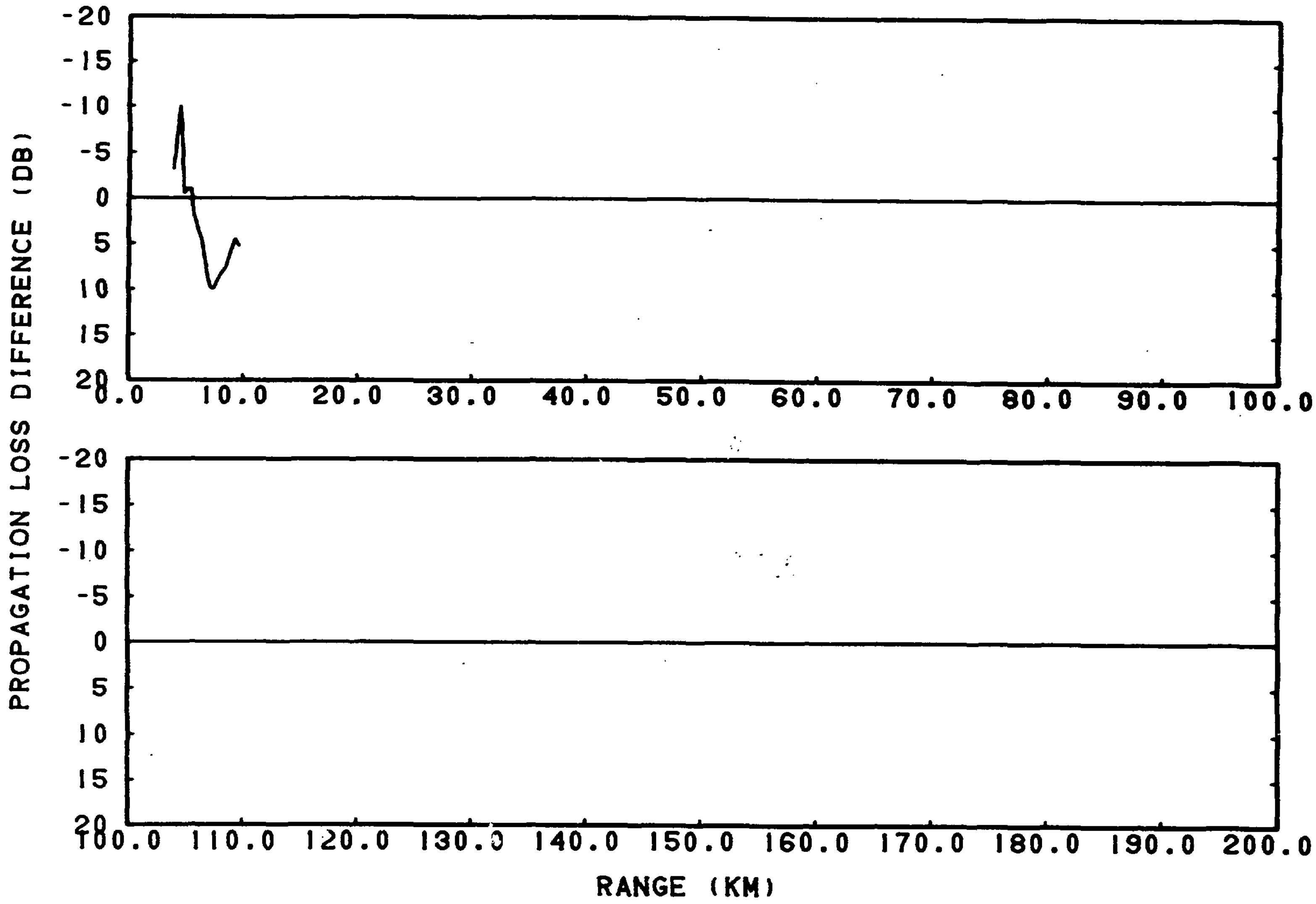
(C) Figure IIIH-53. RAYMODE Incoherent, Run 124, Source Depth = 30.5 Meters, Receiver Depth = 30.5 Meters, Frequency = 1.5 Kilohertz



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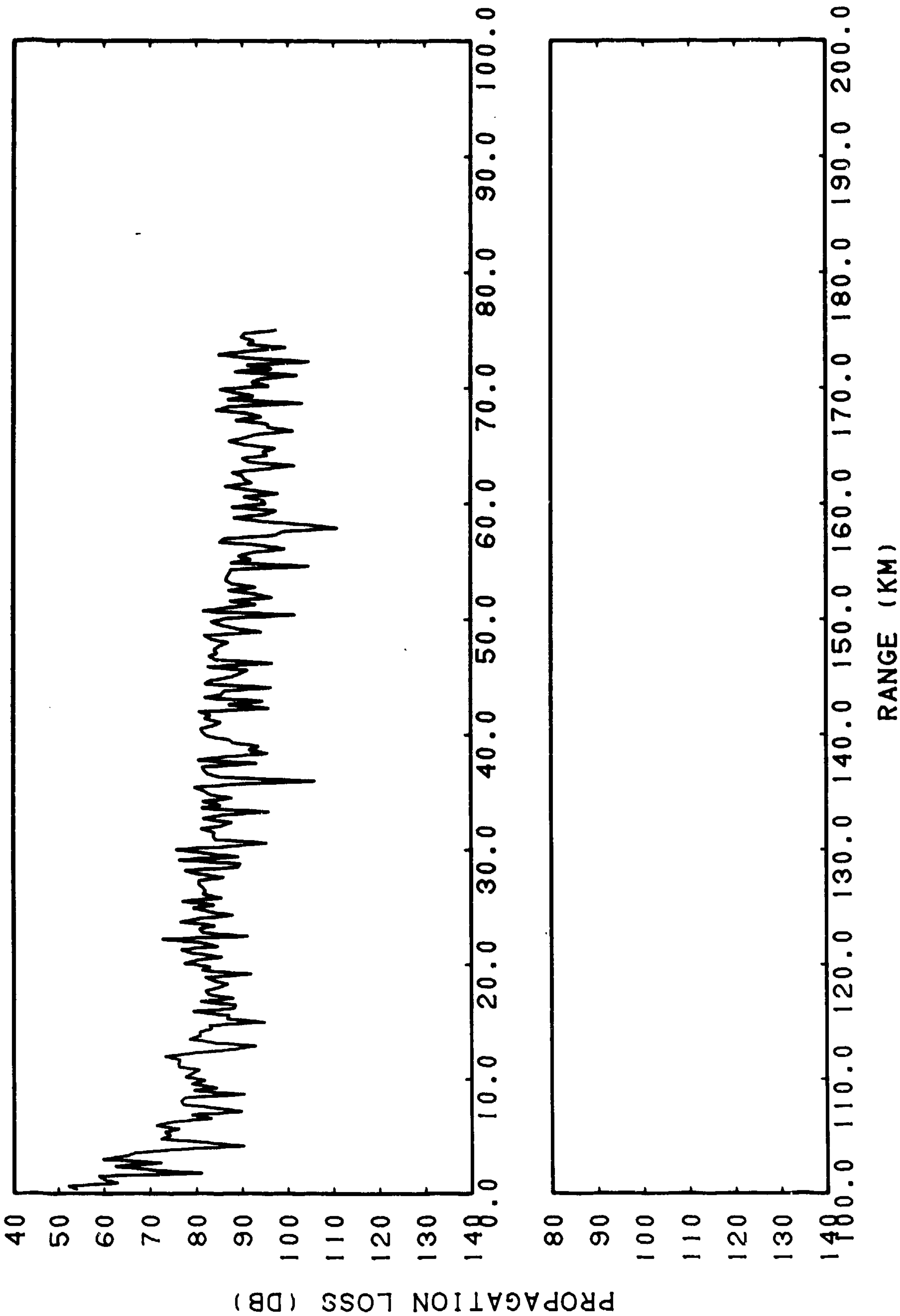
(C) Figure IIIH-54. RAYMODE Incoherent, Run 124, Source Depth = 30.5 Meters, Receiver Depth = 30.5 Meters, Frequency = 1.5 Kilohertz, Subtracted from Smoothed Gulf of Alaska, Run 124, Source Depth = 30.5 Meters, Receiver Depth = 30.5 Meters, Frequency = 1.5 Kilohertz



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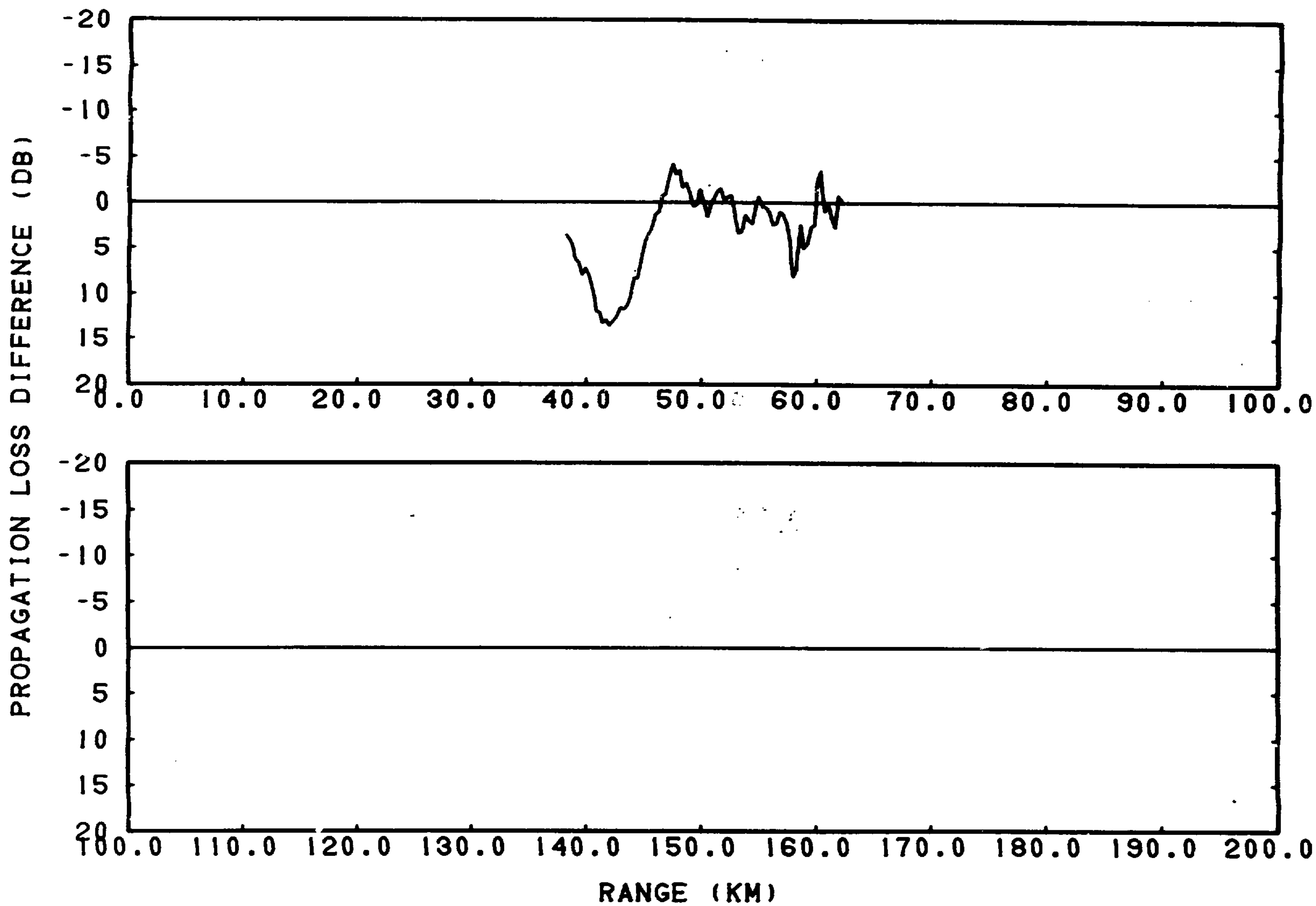
(C) Figure IIIH-55. RAYMODE Coherent, Run 124, Source Depth = 30.5 Meters, Receiver Depth = 305 Meters, Frequency = 1.5 Kilohertz



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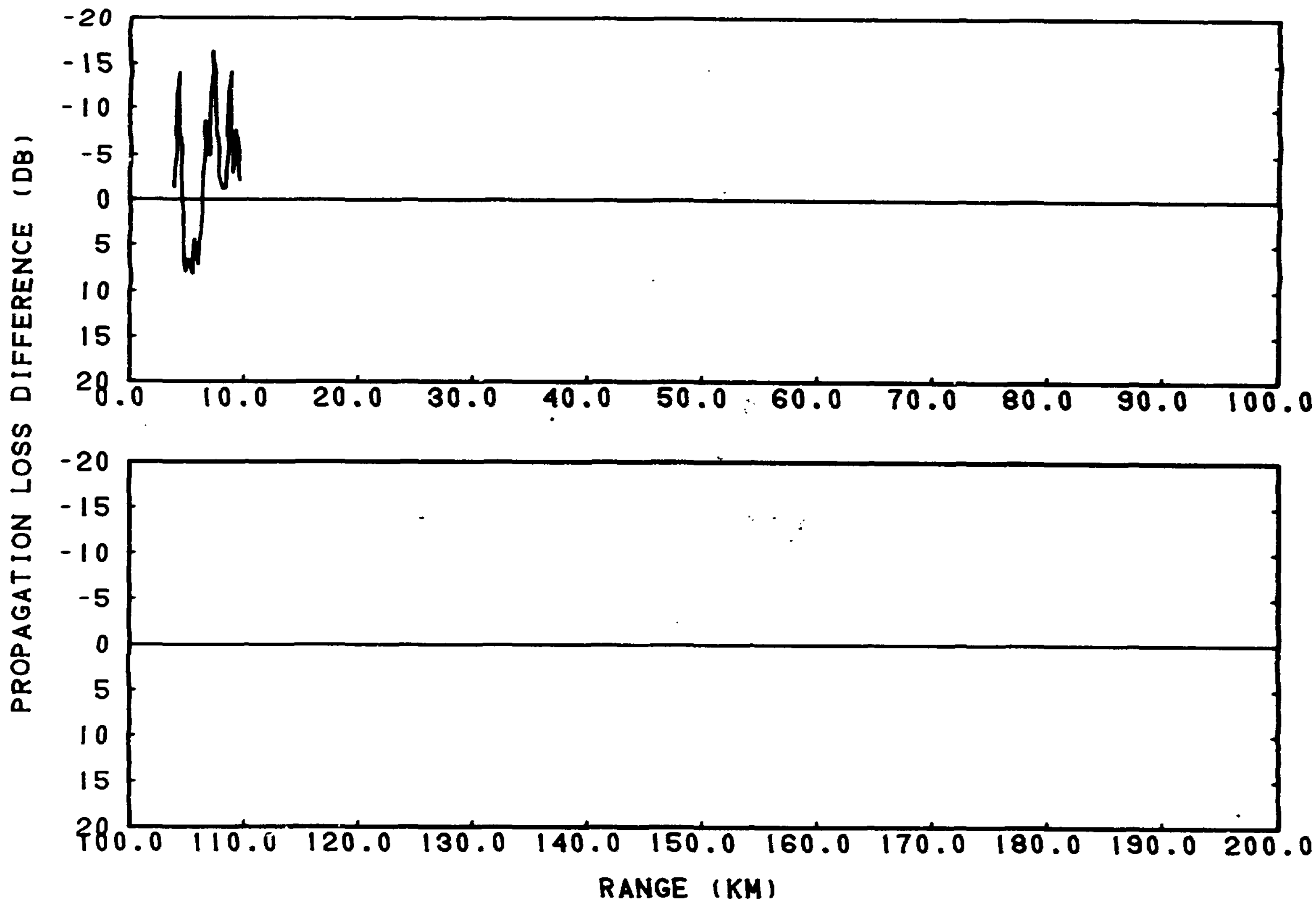
(C) Figure IIIH-56. RAYMODE Incoherent, Run 140, Source Depth = 30.5 Meters, Receiver Depth = 305 Meters, Frequency = 1.5 Kilohertz, Subtracted from Smoothed Gulf of Alaska, Run 140, Source Depth = 30.5 Meters, Receiver Depth = 305 Meters, Frequency = 1.5 Kilohertz



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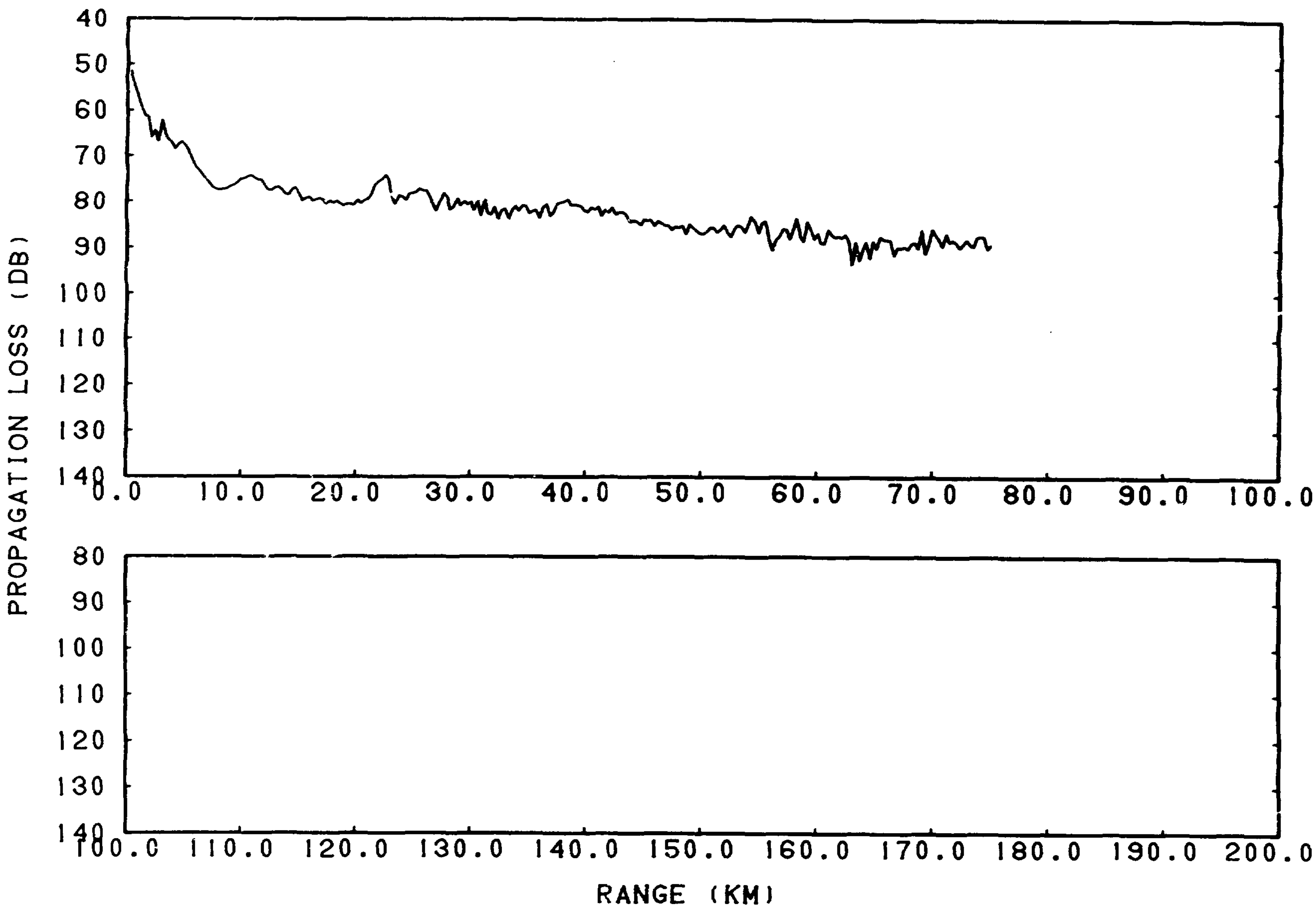
(C) Figure IIIH-57. RAYMODE Coherent, Run 124, Source Depth = 30.5 Meters, Receiver Depth = 305 Meters, Frequency = 1.5 Kilohertz, Subtracted from Smoothed Gulf of Alaska, Run 124, Source Depth = 30.5 Meters, Receiver Depth = 305 Meters, Frequency = 1.5 Kilohertz



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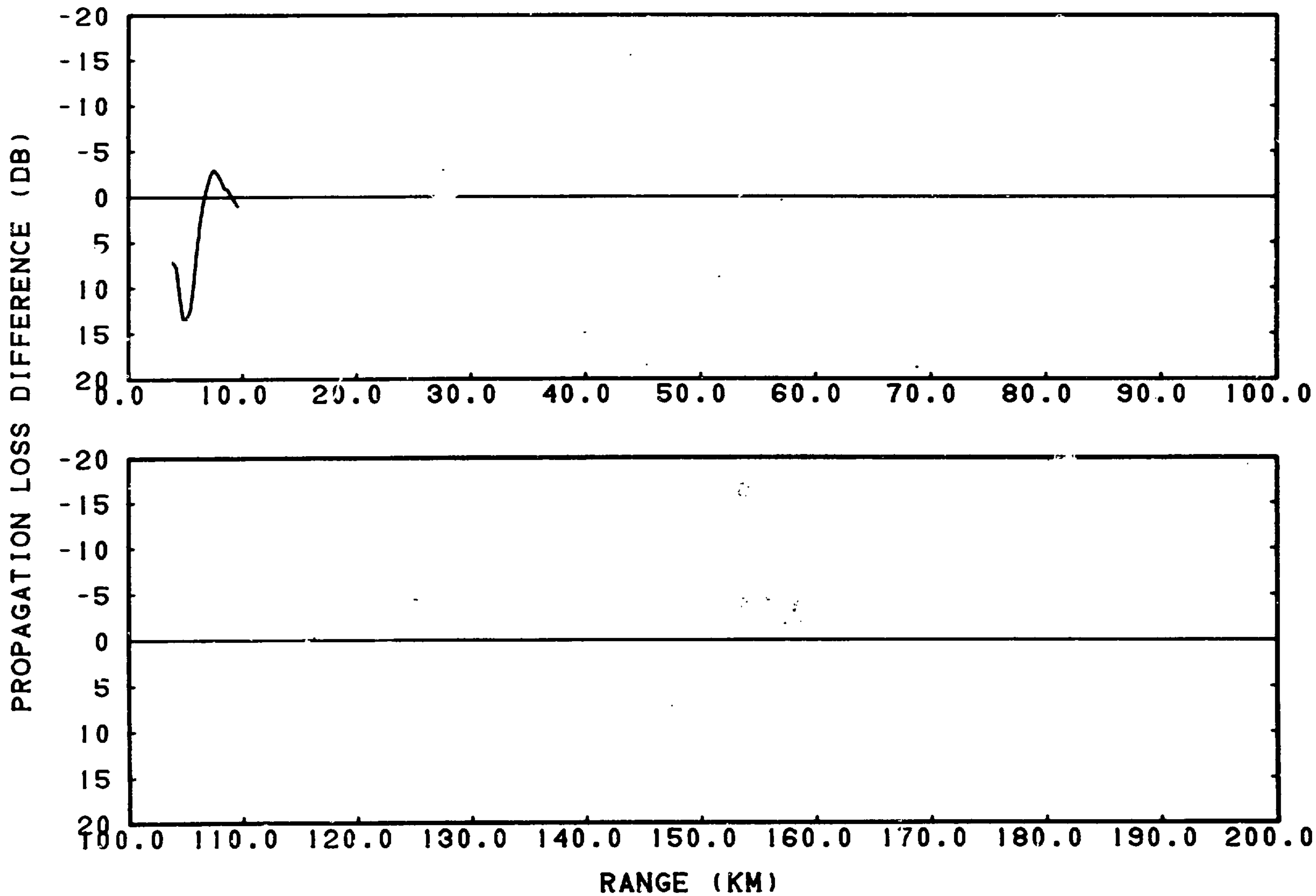
(C) Figure IIIH-58. RAYMODE Incoherent, Run 124, Source Depth = 30.5 Meters, Receiver Depth = 305 Meters, Frequency = 1.5 Kilohertz



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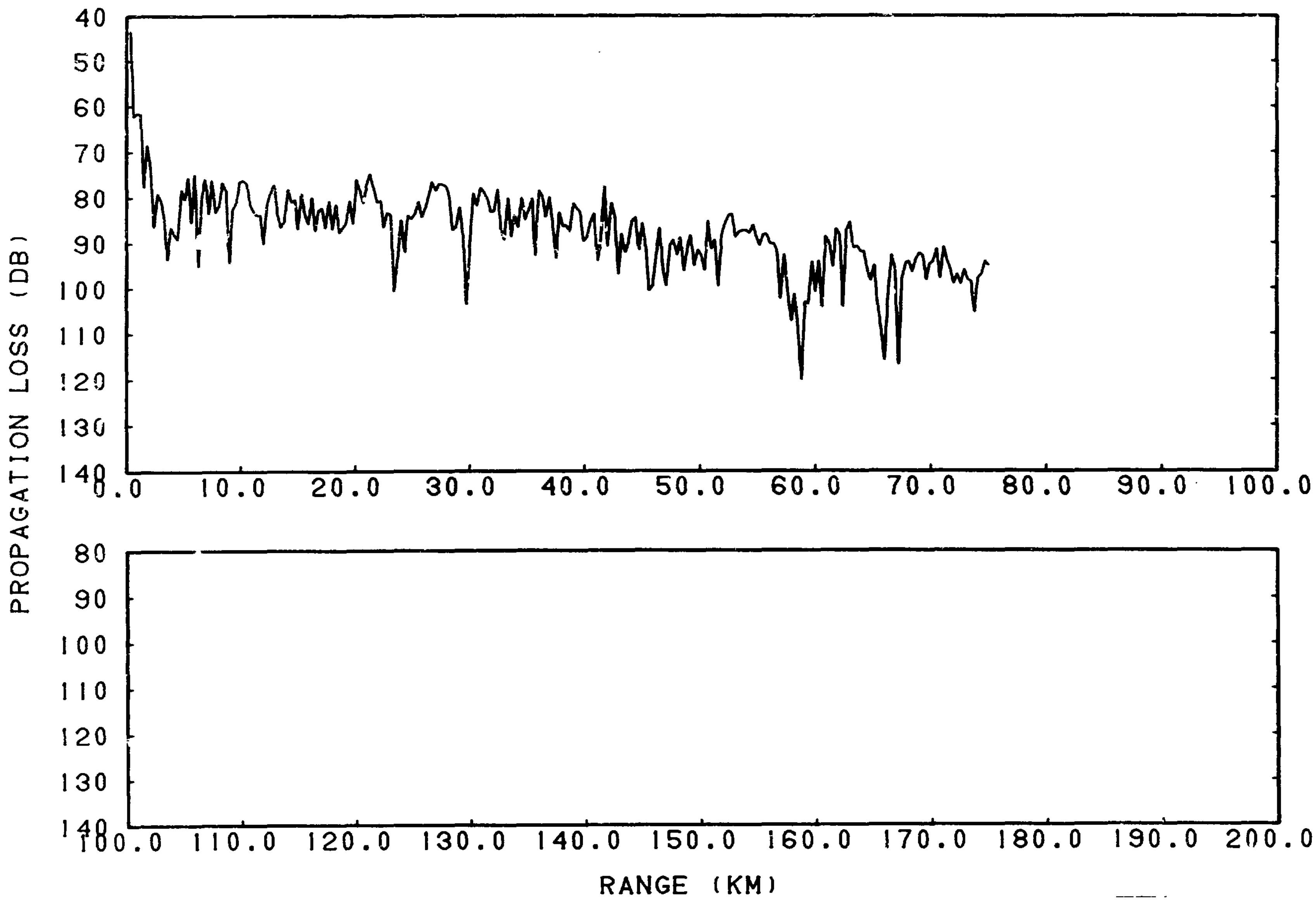
(C) Figure IIIH-59. RAYMODE Incoherent, Run 124, Source Depth = 30.5 Meters, Receiver Depth = 305 Meters, Frequency = 1.5 Kilohertz, Subtracted from Smoothed Gulf of Alaska, Run 124, Source Depth = 30.5 Meters, Receiver Depth = 305 Meters, Frequency = 1.5 Kilohertz



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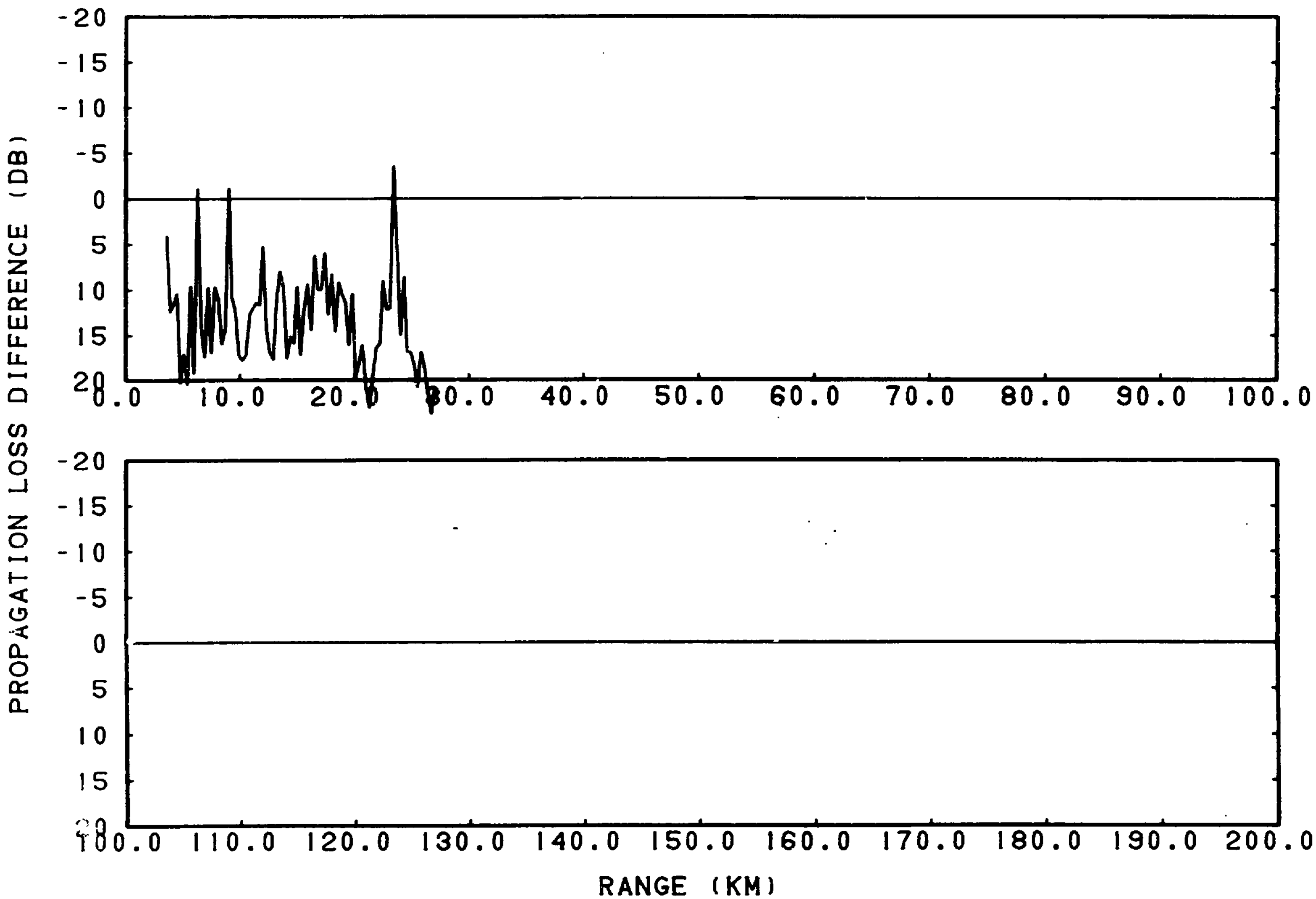
(C) Figure IIIH-60. RAYMODE Coherent, Run 108, Source Depth = 1067 Meters, Receiver Depth = 30.5 Meters, Frequency = 2.5 Kilohertz



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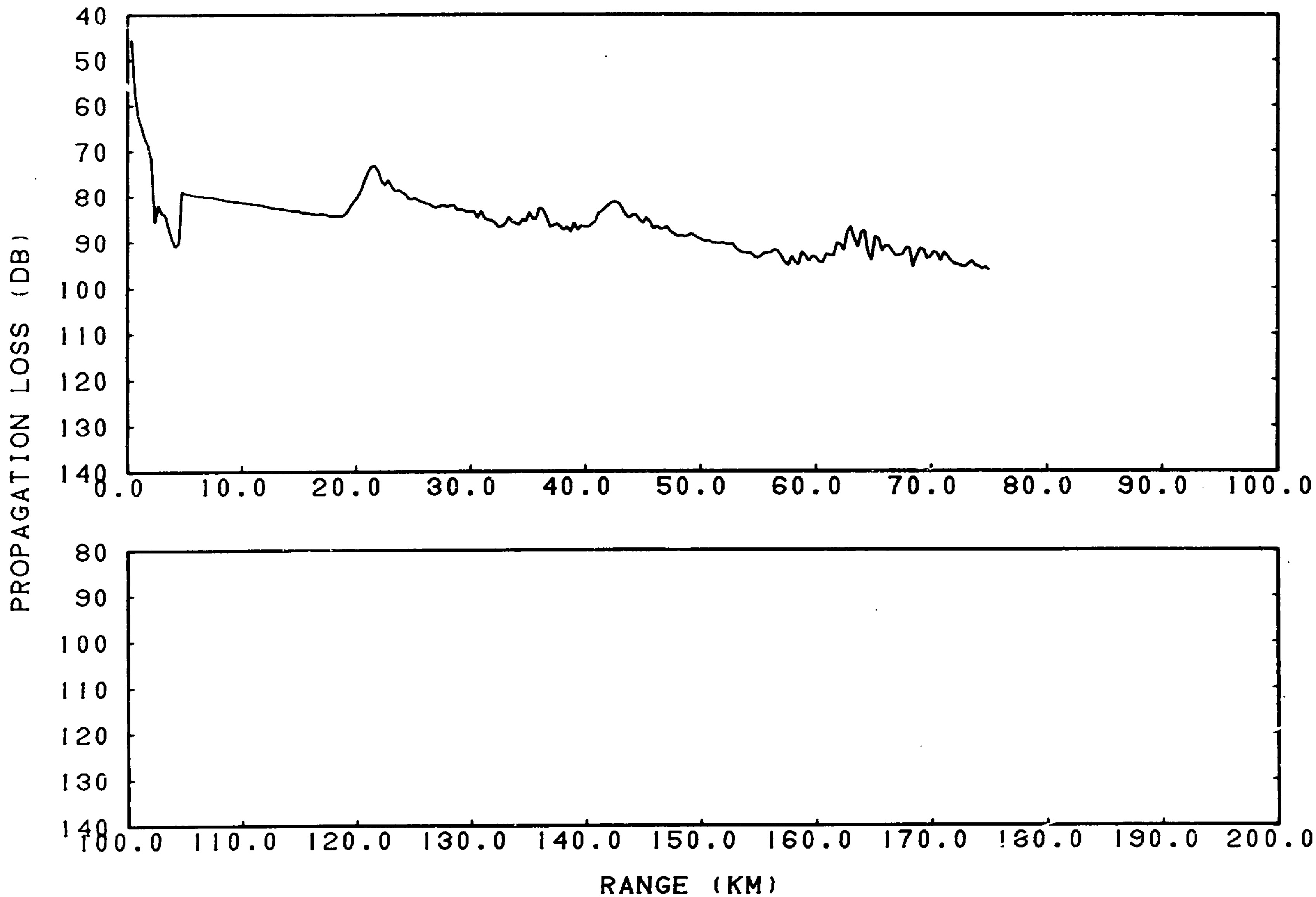
(C) Figure IIIH-61. RAYMODE Coherent, Run 108, Source Depth = 1067 Meters, Receiver Depth = 30.5 Meters, Frequency = 2.5 Kilohertz, Subtracted from Smoothed Gulf of Alaska, Run 108, Source Depth = 1067 Meters, Receiver Depth = 30.5 Meters, Frequency = 2.5 Kilohertz



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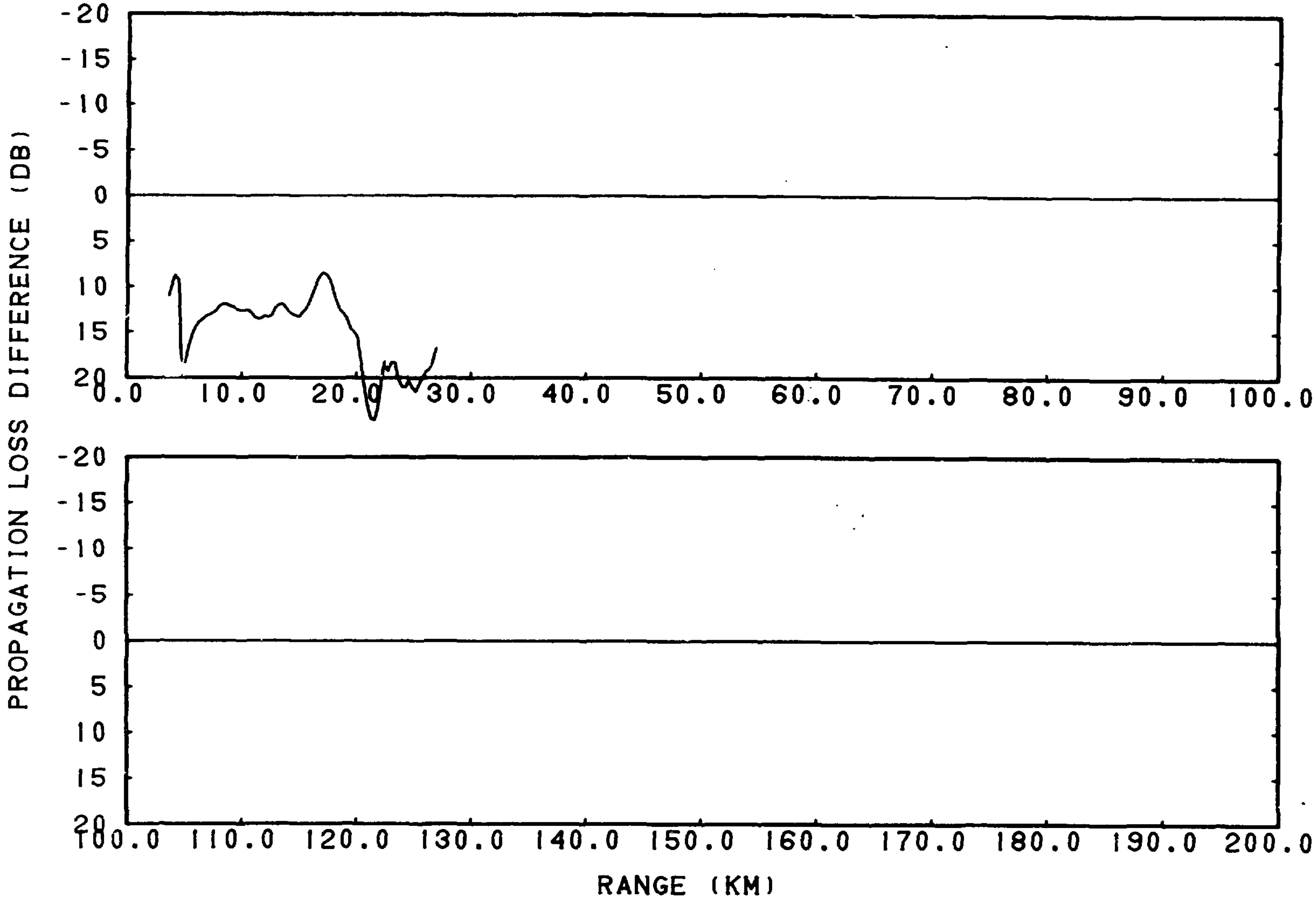
(C) Figure IIIH-62. RAYMODE Incoherent, Run 108, Source Depth = 1067 Meters, Receiver Depth = 30.5 Meters, Frequency = 2.5 Kilohertz



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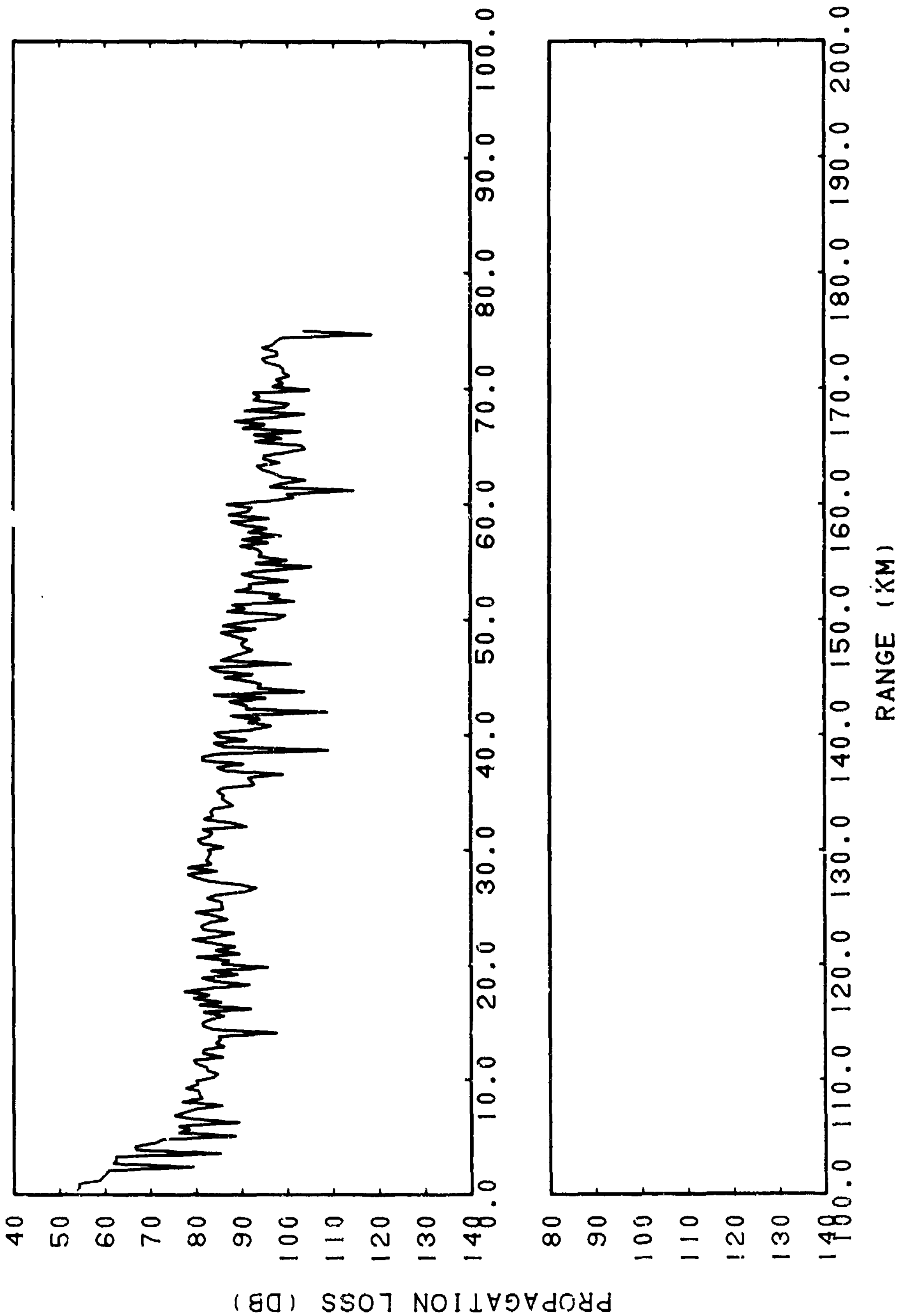
(C) Figure IIIH-63. RAYMODE Incoherent, Run 108, Source Depth = 1067 Meters, Receiver Depth = 30.5 Meters, Frequency = 2.5 Kilohertz, Subtracted from Smoothed Gulf of Alaska, Run 108, Source Depth = 1067 Meters, Receiver Depth = 30.5 Meters, Frequency = 2.5 Kilohertz



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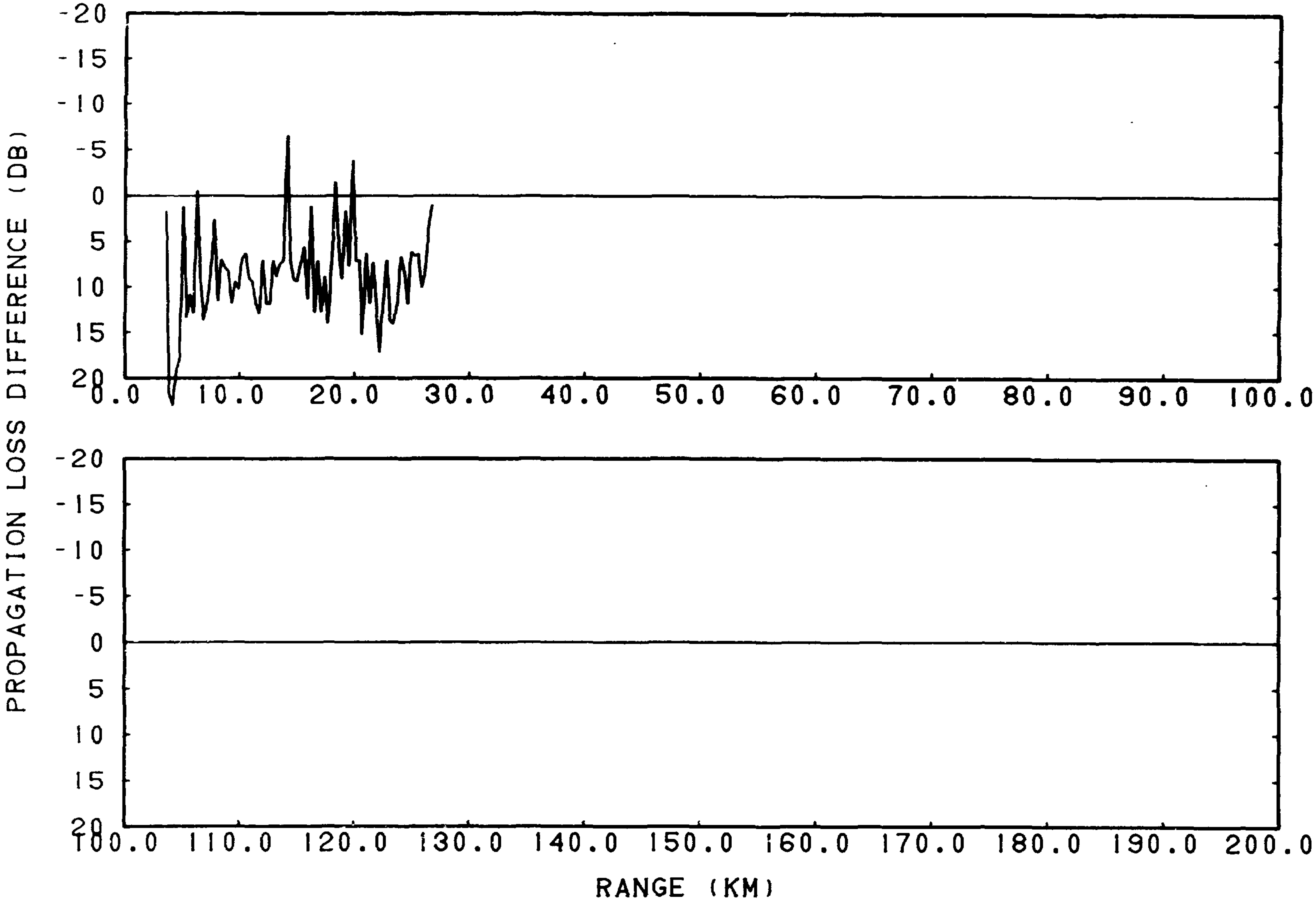
(C) Figure IIIH-64. RAYMODE Coherent, Run 108, Source Depth = 1067 Meters, Receiver Depth = 305 Meters, Frequency = 2.5 Kilohertz



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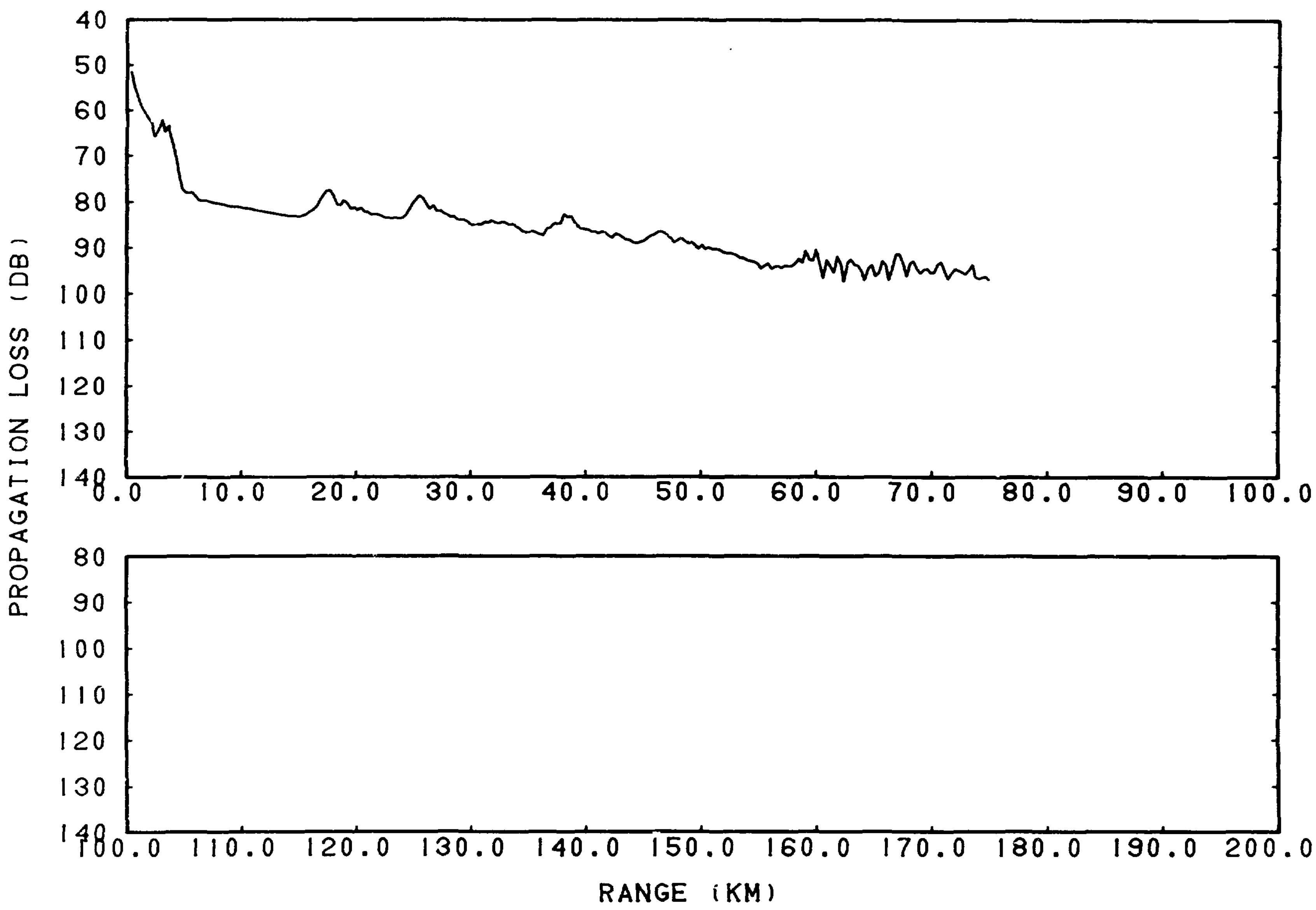
(C) Figure IIIH-65. RAYMODE Coherent, Run 108, Source Depth = 1067 Meters, Receiver Depth = 305 Meters, Frequency = 2.5 Kilohertz, Subtracted from Smoothed Gulf of Alaska, Run 108, Source Depth = 305 Meters, Receiver Depth = 305 Meters, Frequency = 2.5 Kilohertz



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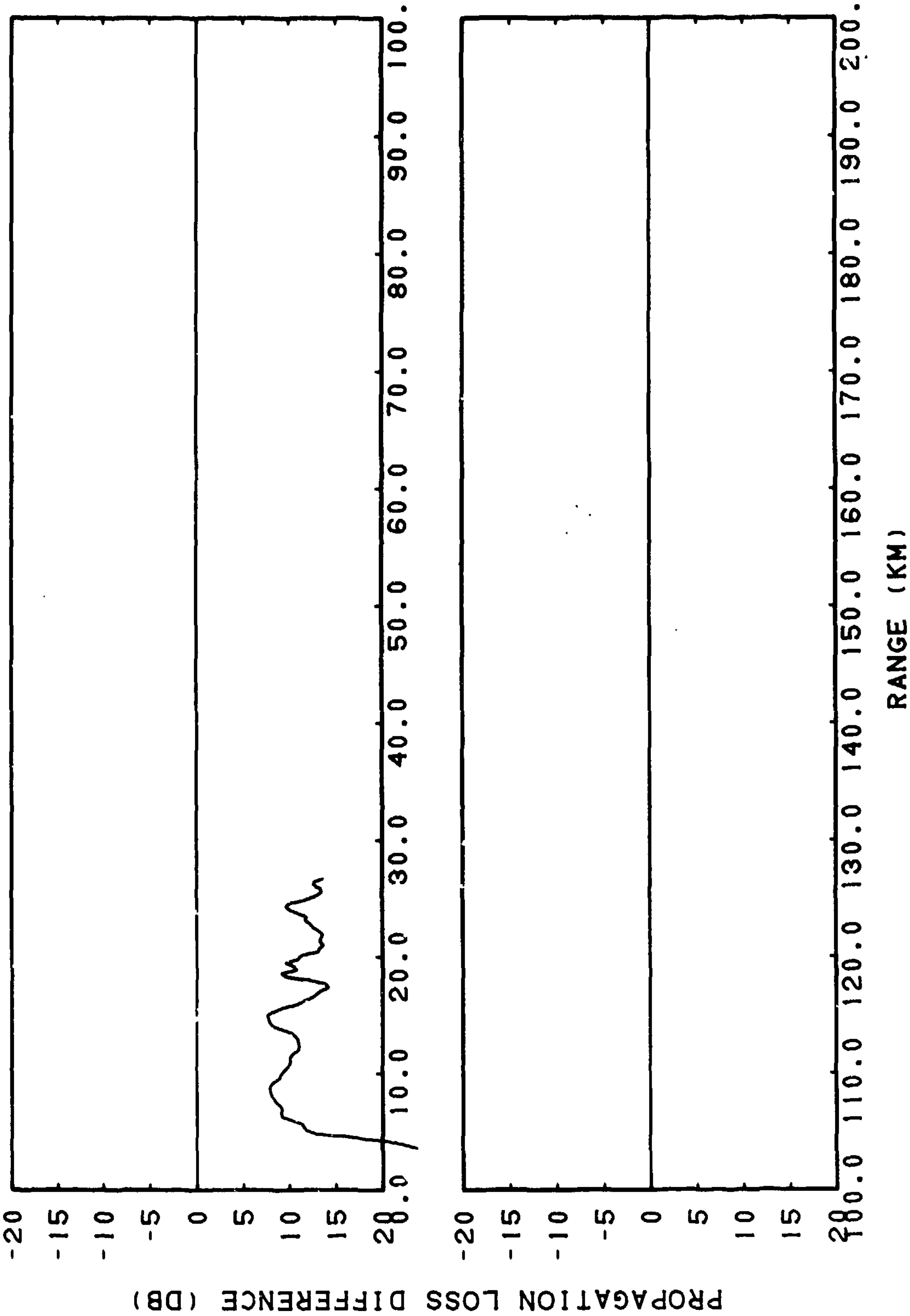
(C) Figure IIIH-66. RAYMODE Incoherent, Run 108, Source Depth = 1067 Meters, Receiver Depth = 305 Meters, Frequency = 2.5 Kilohertz



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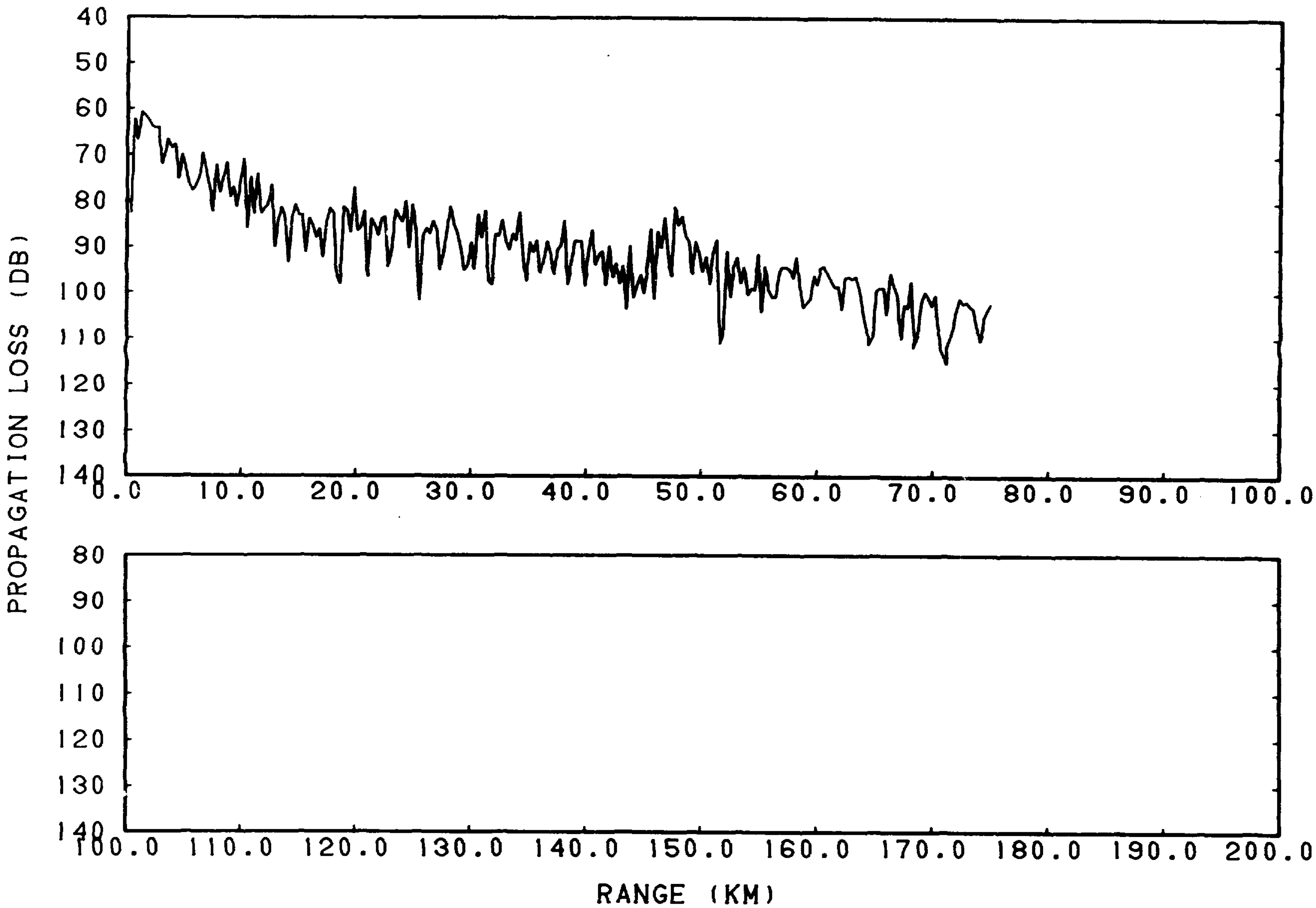
(C) Figure IIIH-67. RAYMODE Incoherent, Run 108, Source Depth = 1067 Meters, Receiver Depth = 305 Meters, Frequency = 2.5 Kilohertz, Subtracted from Smoothed Gulf of Alaska, Run 108, Source Depth = 1067 Meters, Receiver Depth = 305 Meters, Frequency = 2.5 Kilohertz



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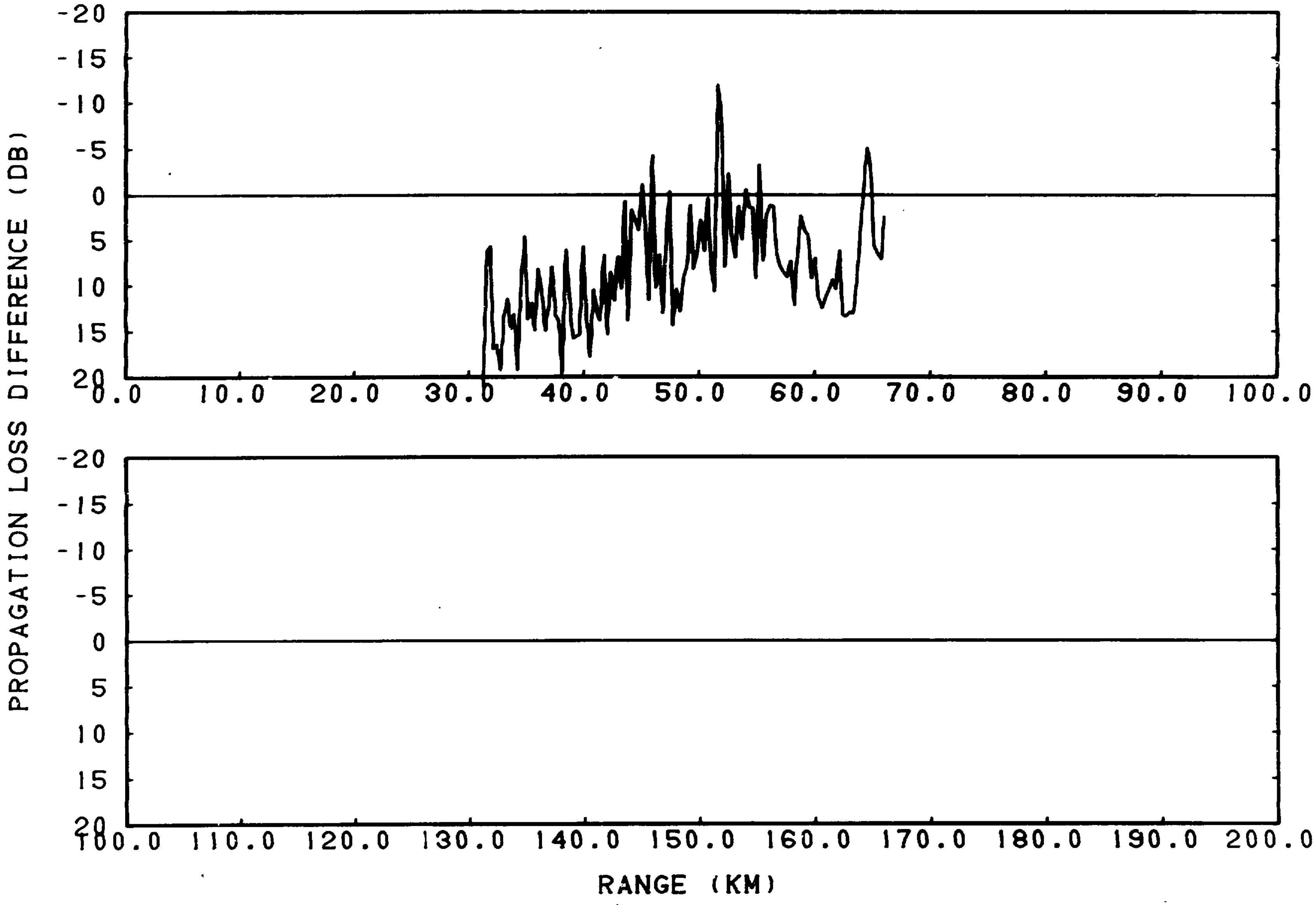
(C) Figure IIIH-68. RAYMODE Coherent, Run 107, Source Depth = 1067 Meters, Receiver Depth = 30.5 Meters, Frequency = 2.5 Kilohertz



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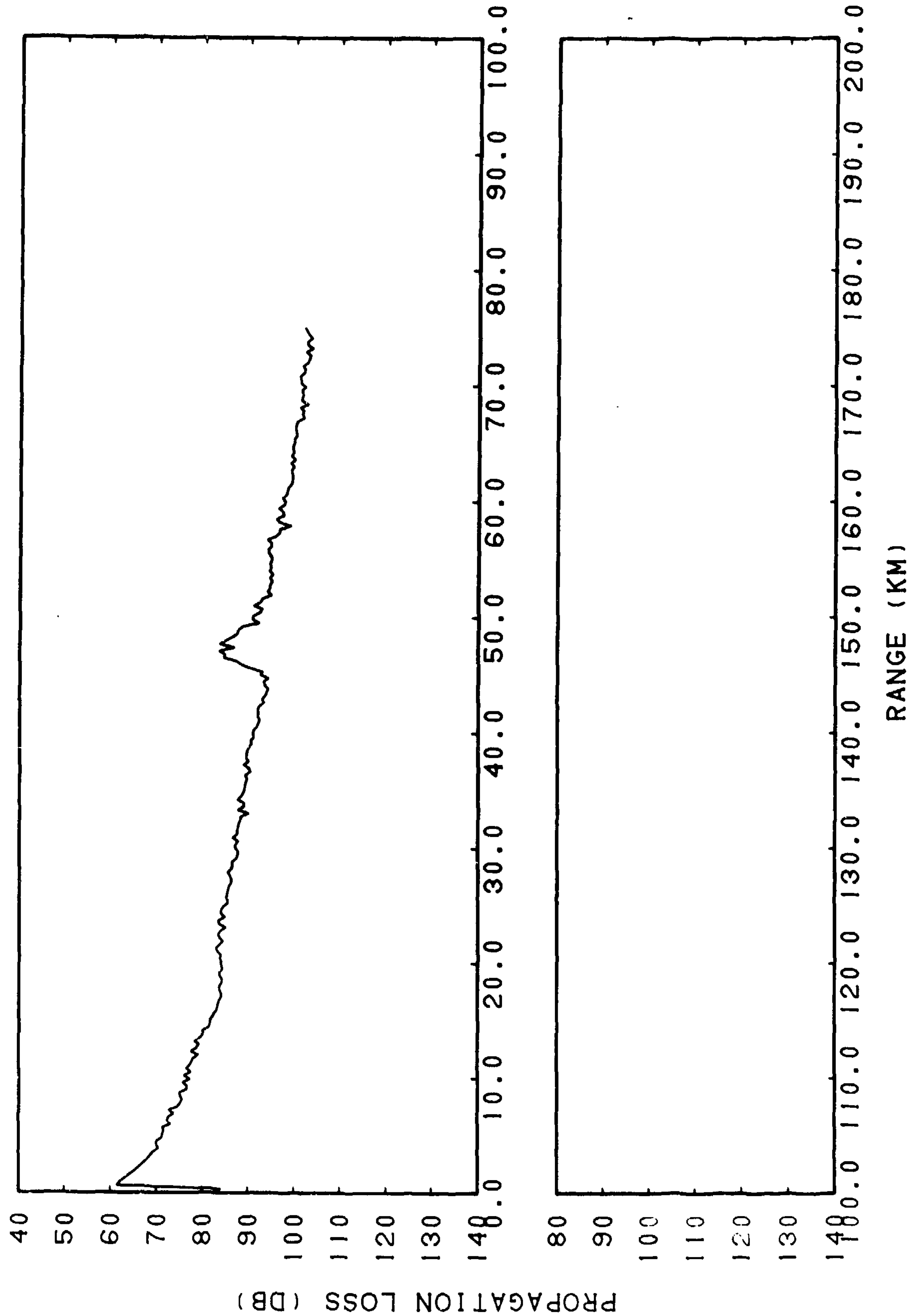
(C) Figure IIIH-69. RAYMODE Coherent, Run 107, Source Depth = 1067 Meters, Receiver Depth = 30.5 Meters, Frequency = 2.5 Kilohertz, Subtracted from Smoothed Gulf of Alaska, Run 107, Source Depth = 1067 Meters, Receiver Depth = 30.5 Meters, Frequency = 2.5 Kilohertz



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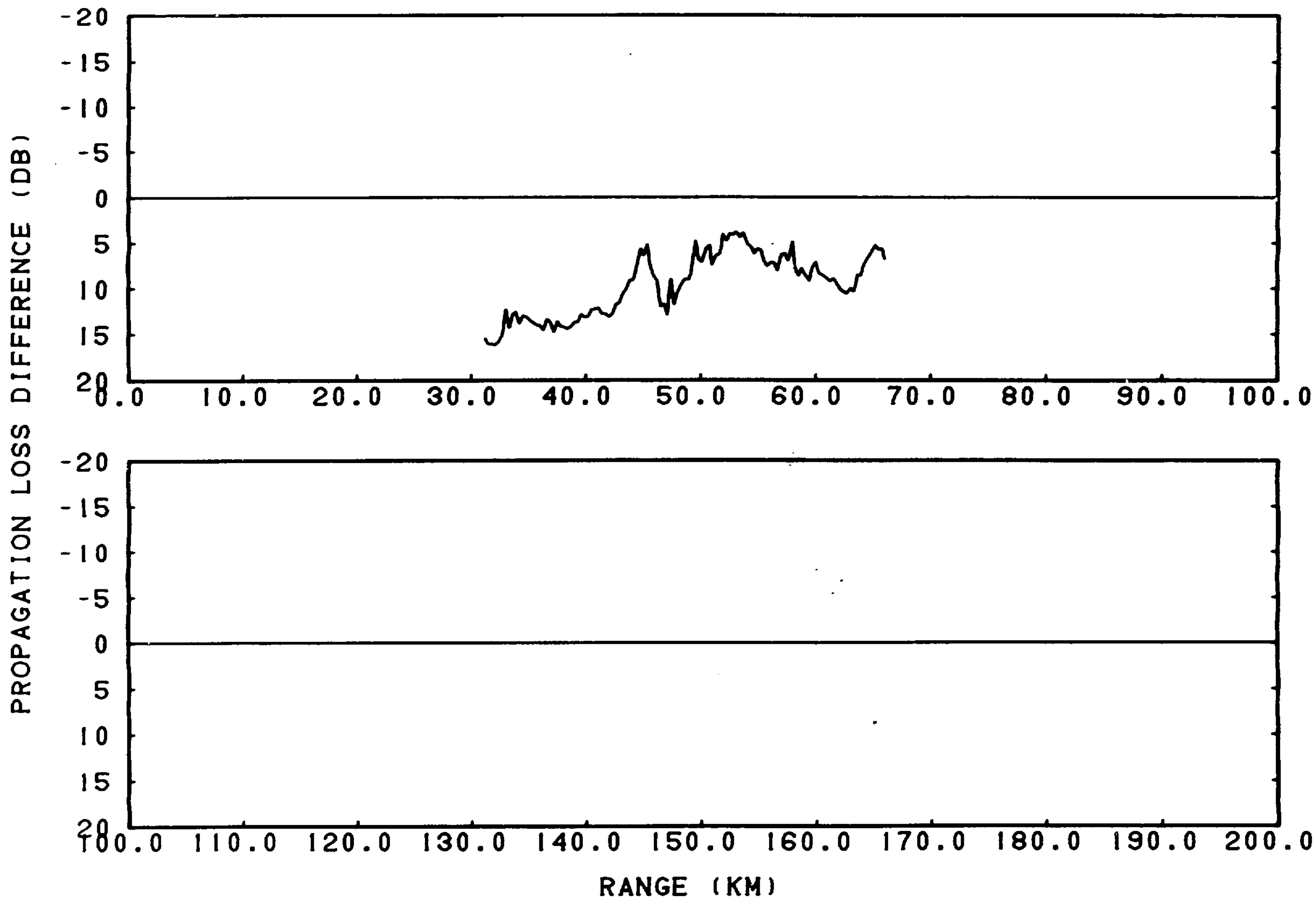
(C) Figure IIIH-70. RAYMODE Incoherent, Run 107, Source Depth = 1067 Meters, Receiver Depth = 30.5 Meters, Frequency = 2.5 Kilohertz



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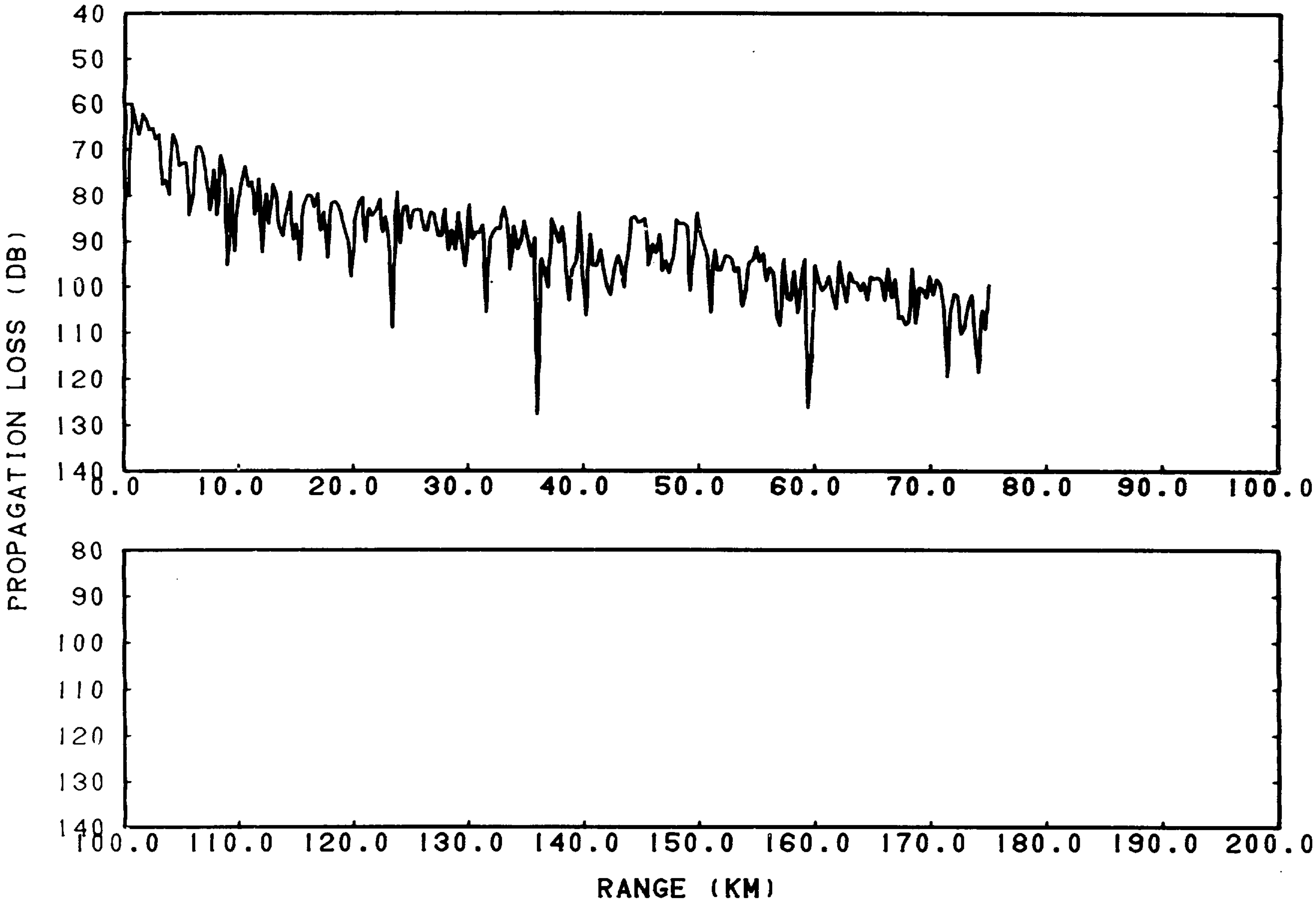
(C) Figure IIIH-71. RAYMODE Incoherent, Run 107, Source Depth = 1067 Meters, Receiver Depth = 30.5 Meters, Frequency = 2.5 Kilohertz, Subtracted from Smoothed Gulf of Alaska, Run 107, Source Depth = 1067 Meters, Receiver Depth = 30.5 Meters, Frequency = 2.5 Kilohertz



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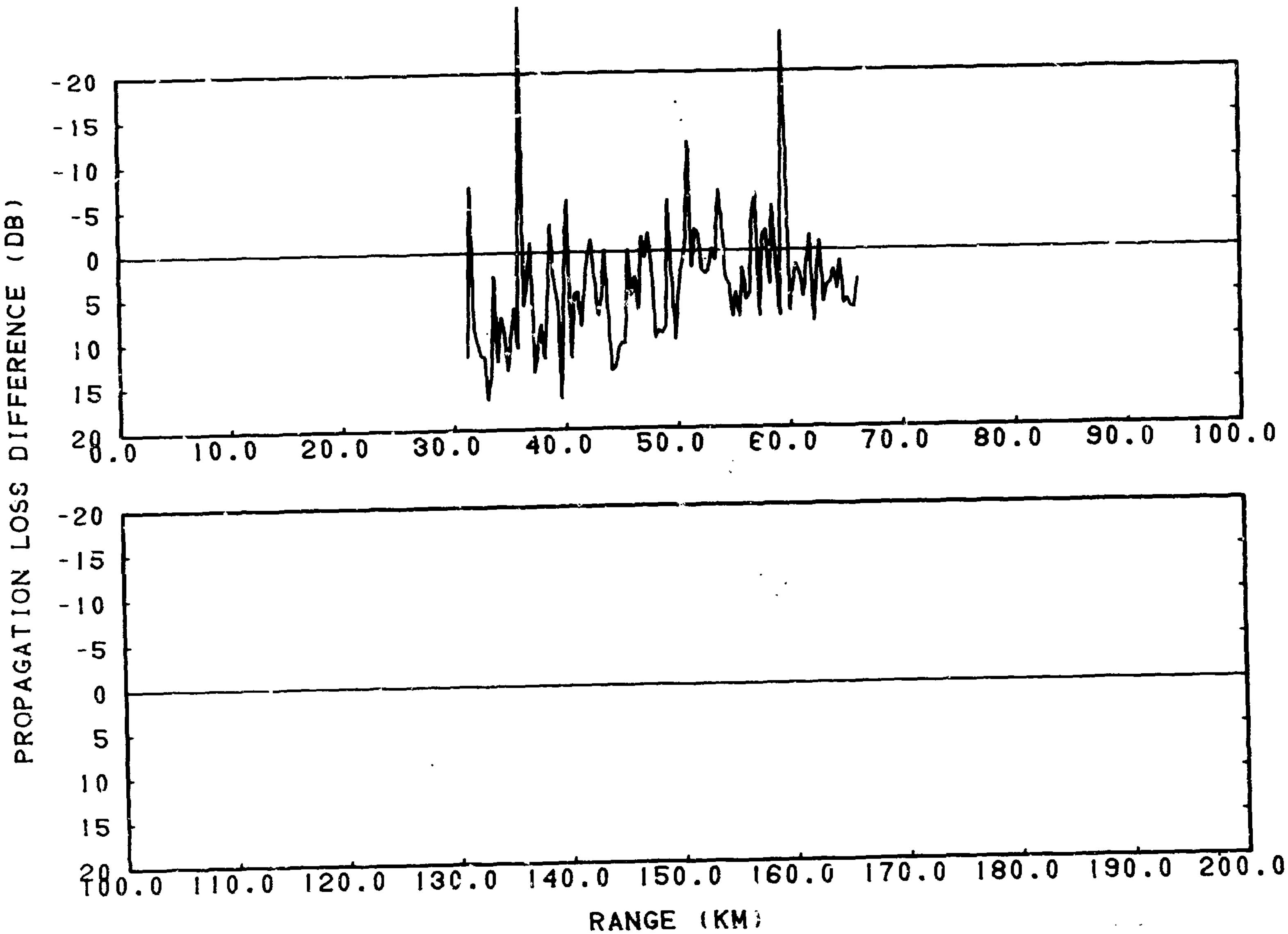
(C) Figure IIIH-72. RAYMODE Coherent, Run 107, Source Depth = 1067 Meters, Receiver Depth = 305 Meters, Frequency = 2.5 Kilohertz



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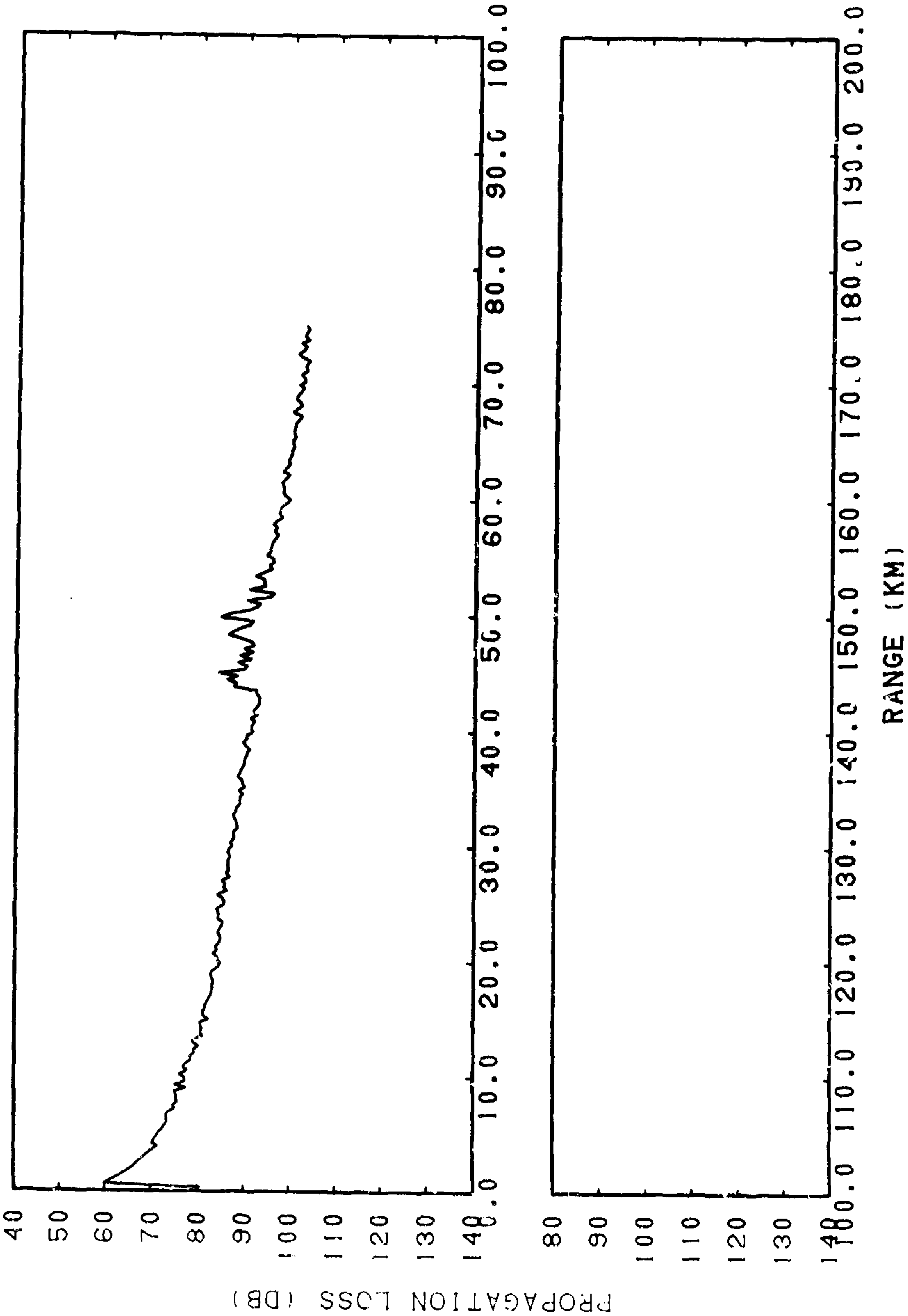
(C) Figure IIIH-73. RAYMODE Coherent, Run 107, Source Depth = 1067 Meters, Receiver Depth = 305 Meters, Frequency = 2.5 Kilohertz Subtracted from Smoothed Gulf of Alaska, Run 107, Source Depth = 1067 Meters, Receiver Depth = 305 Meters, Frequency = 2.5 Kilohertz



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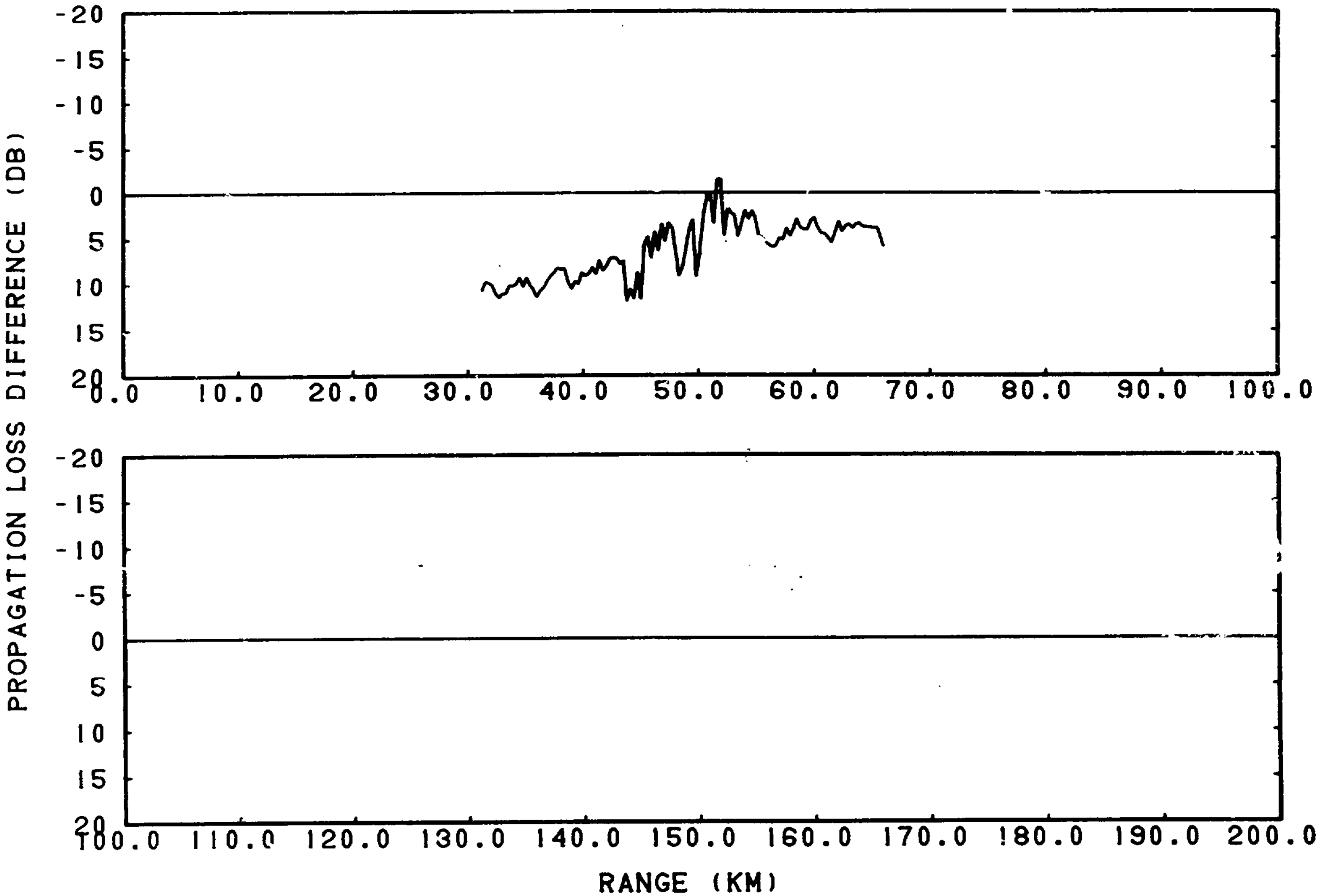
(C) Figure IIIH-74. RAYMODE Incoherent, Run 107, Source Depth = 1067 Meters, Receiver Depth = 305 Meters, Frequency = 2.5 Kilohertz



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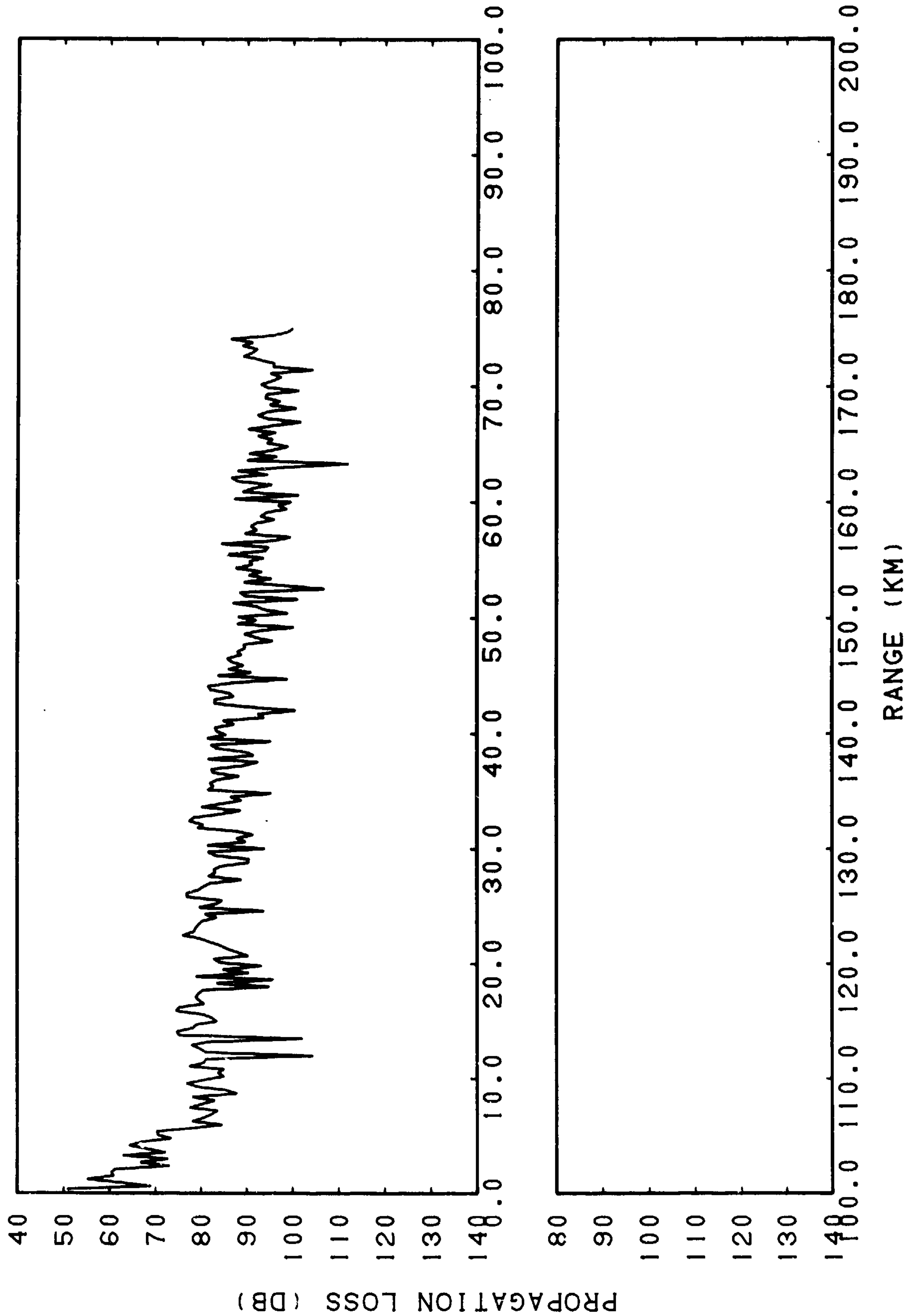
(C) Figure IIIH-75. RAYMODE Incoherent, Run 107, Source Depth = 1067 Meters, Receiver Depth = 305 Meters, Frequency = 2.5 Kilohertz, Subtracted from Smoothed Gulf of Alaska, Run 107, Source Depth = 1067 Meters, Receiver Depth = 305 Meters, Frequency = 2.5 Kilohertz



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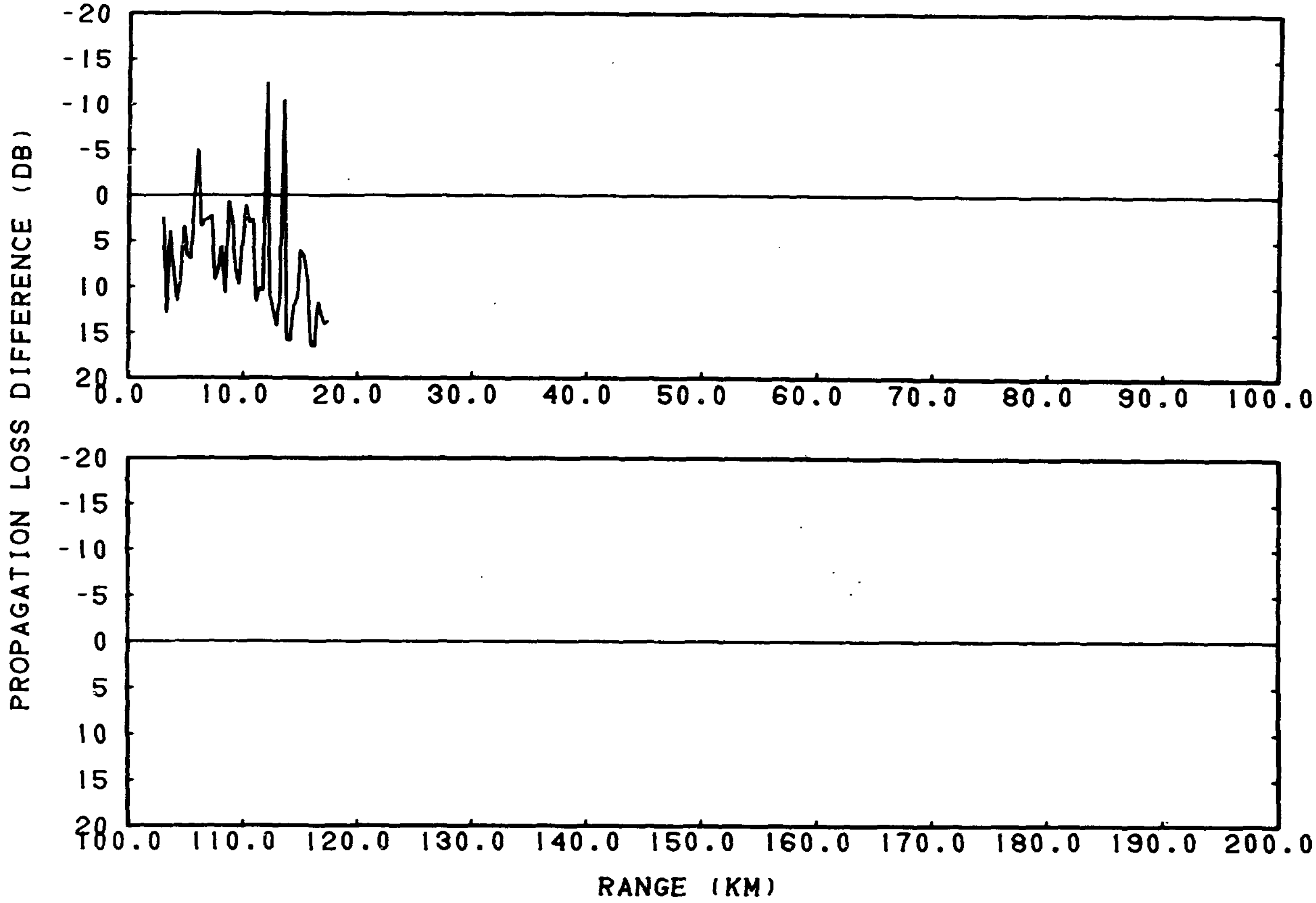
(C) Figure IIIH-76. RAYMODE Coherent, Run 112B, Source Depth = 305 Meters, Receiver Depth = 30.5 Meters, Frequency = 2.5 Kilohertz



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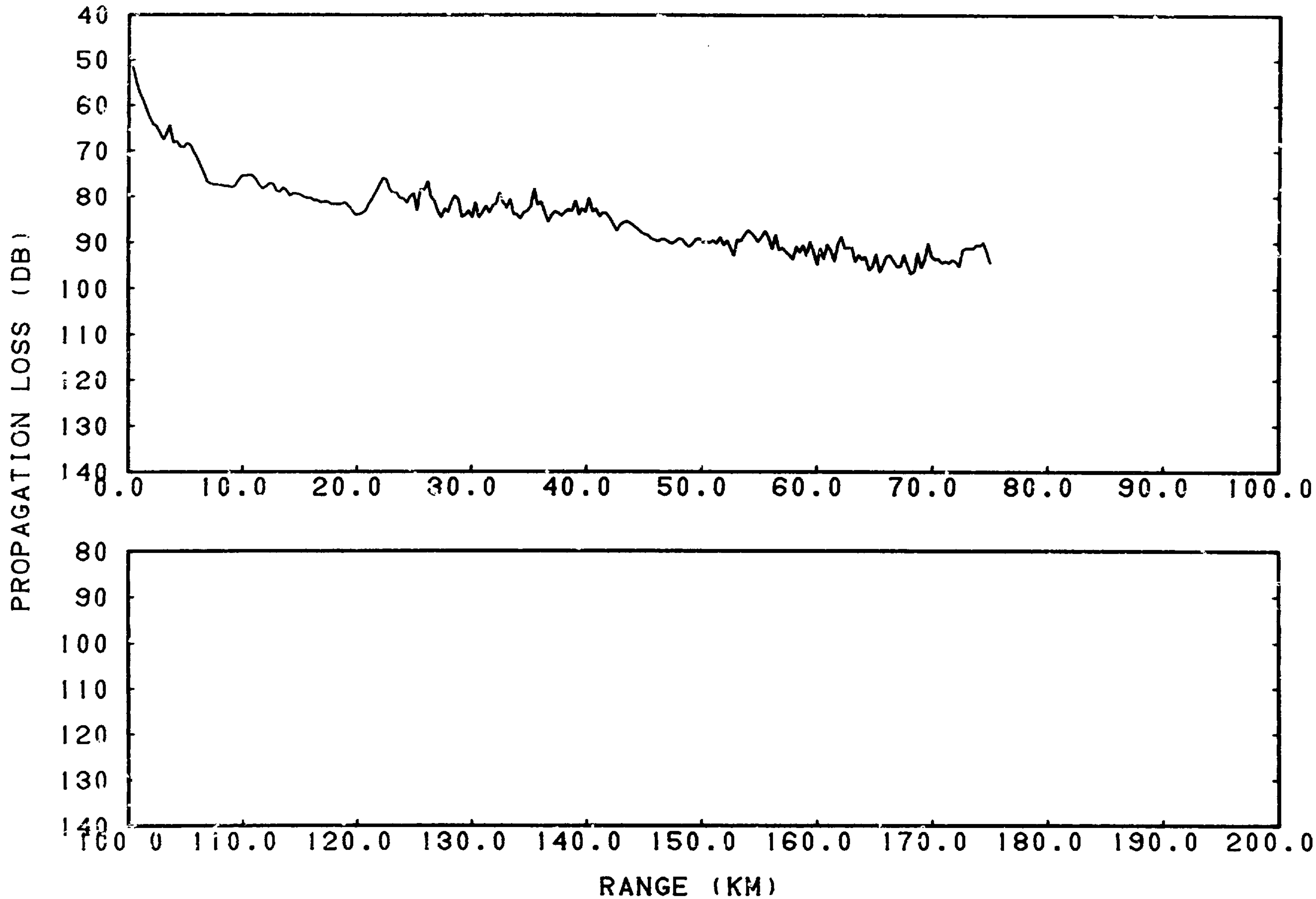
(C) Figure IIIH-77. RAYMODE Coherent, Run 112B, Source Depth = 305 Meters, Receiver Depth = 30.5 Meters, Frequency = 2.5 Kilohertz, Subtracted from Smoothed Gulf of Alaska, Run 112B, Source Depth = 305 Meters, Receiver Depth = 30.5 Meters, Frequency = 2.5 Kilohertz



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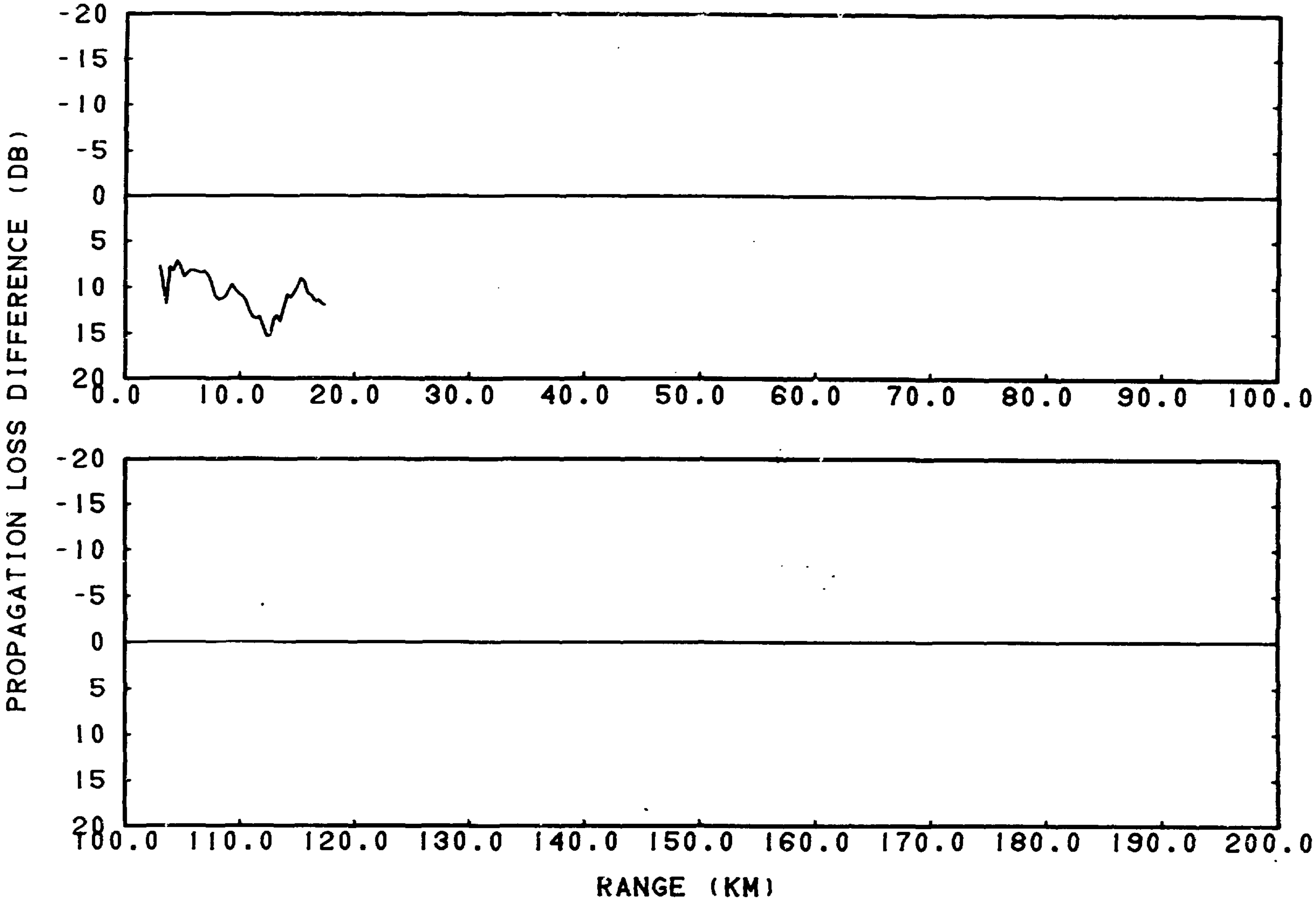
(C) Figure IIIH-78. RAYMODE Incoherent, Run 112B, Source Depth = 305 Meters, Receiver Depth = 30.5 Meters, Frequency = 2.5 Kilohertz



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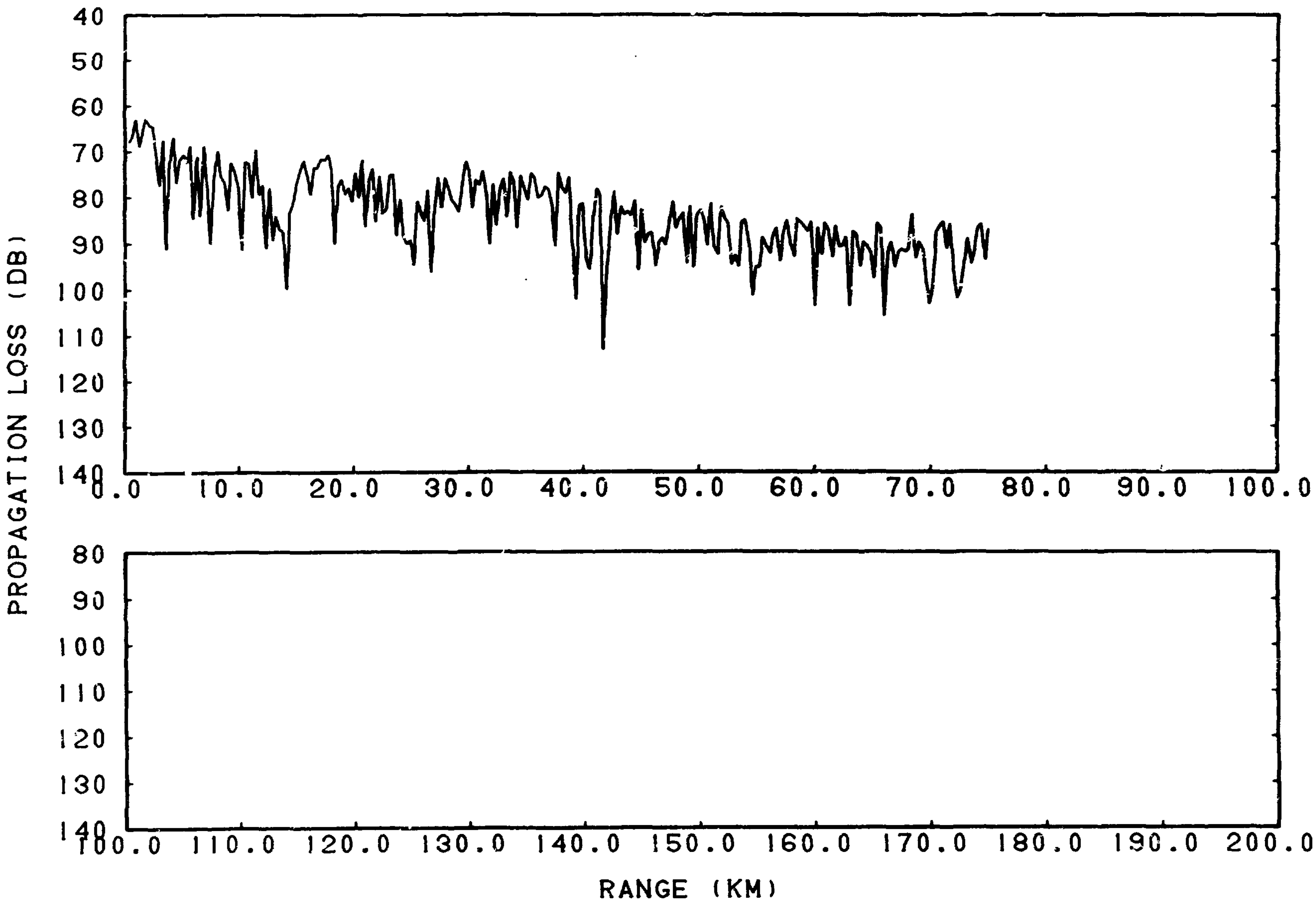
(C) Figure IIIH-79. RAYMODE Incoherent, Run 112B, Source Depth = 305 Meters, Receiver Depth = 30.5 Meters, Frequency = 2.5 Kilohertz, Subtracted from *Smoothed Gulf of Alaska*, Run 112B, Source Depth = 305 Meters, Receivcr Depth = 30.5 Meters, Frequency = 2.5 Kilohertz



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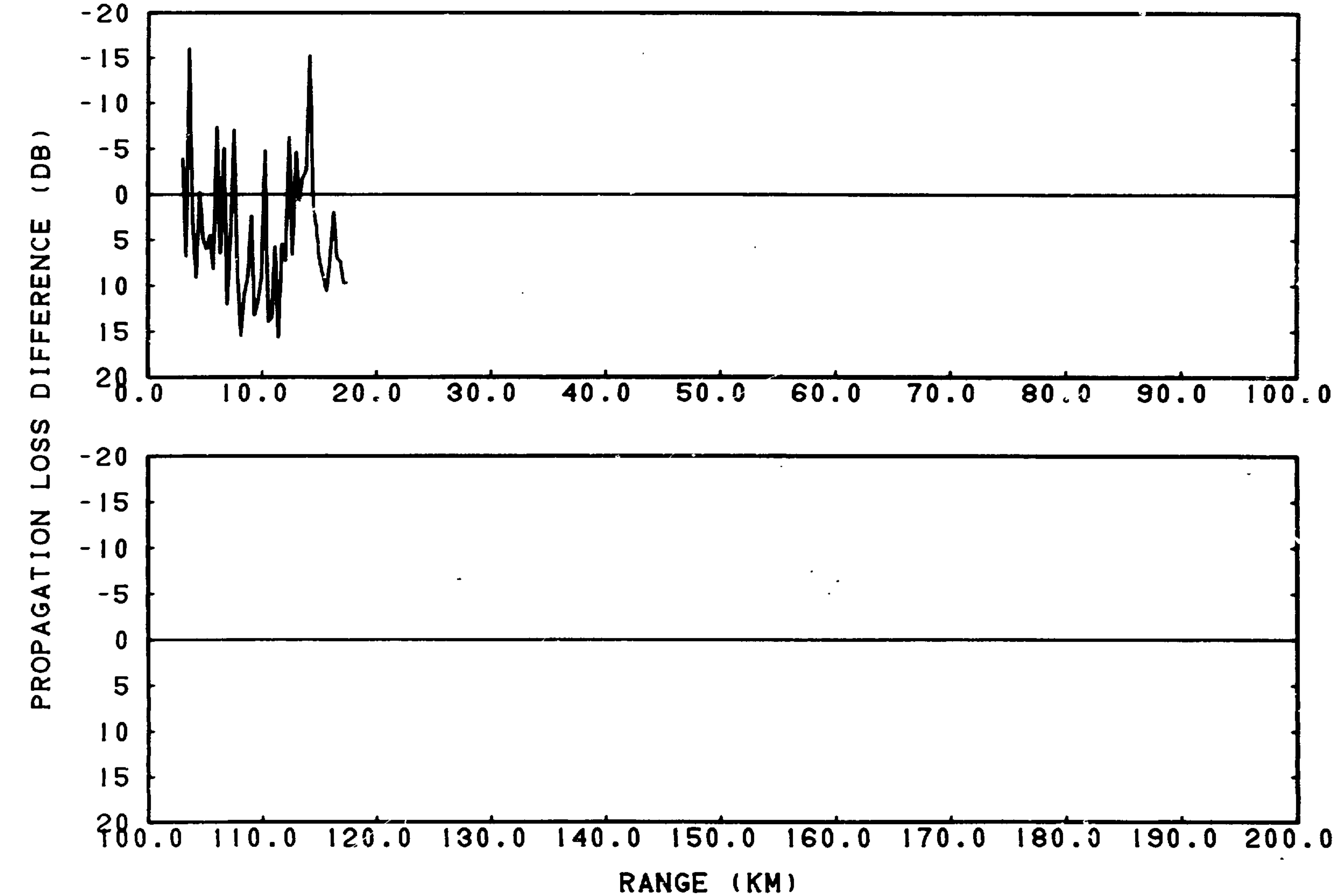
(C) Figure IIIH-80. RAYMODE Coherent, Run 112B, Source Depth = 305 Meters, Receiver Depth = 305 Meters, Frequency = 2.5 Kilohertz



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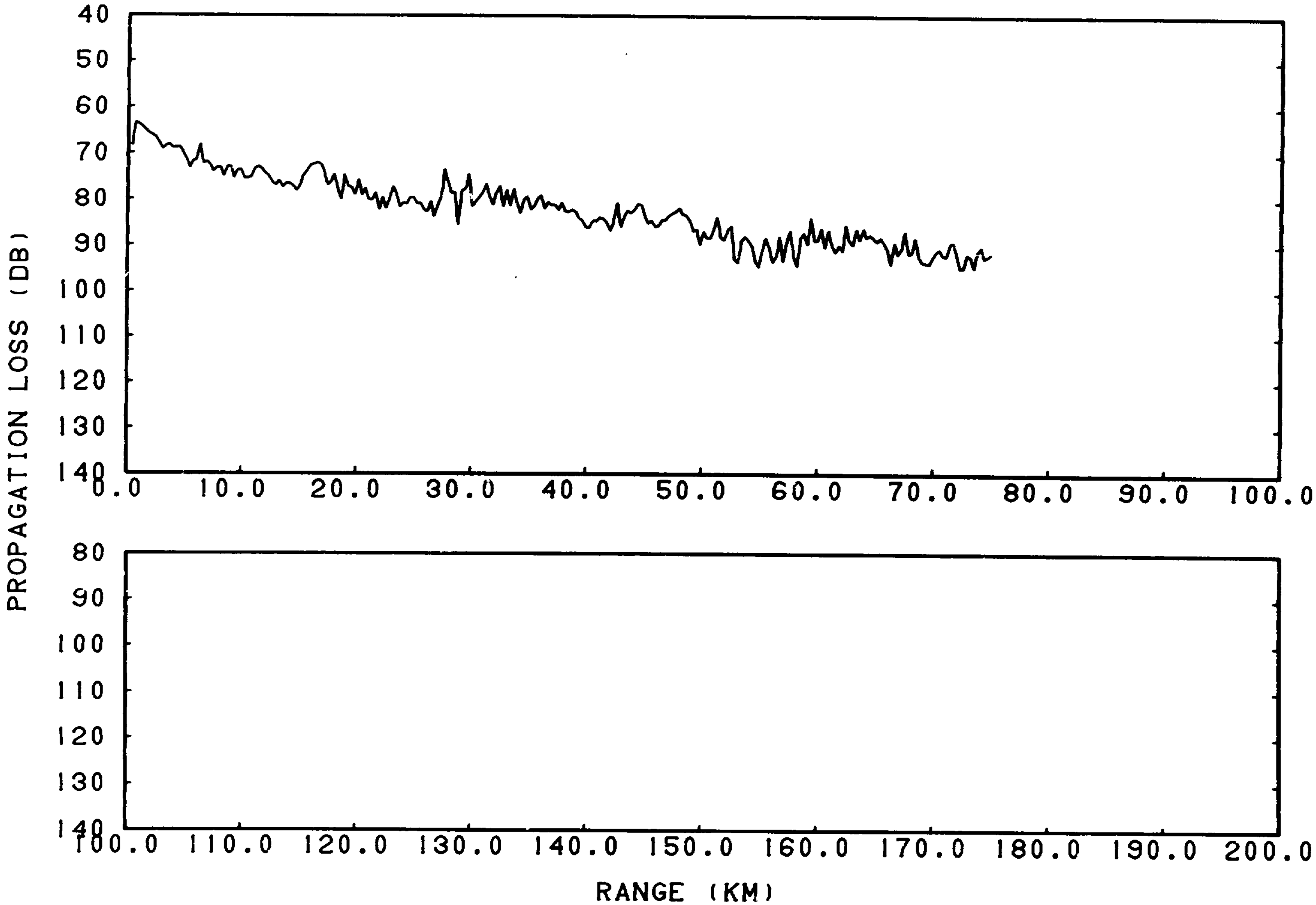
(C) Figure IIIH-81. RAYMODE Coherent, Run 112B, Source Depth = 305 Meters, Receiver Depth = 305 Meters, Frequency = 2.5 Kilohertz Subtracted from Smoothed Gulf of Alaska, Run 112B, Source Depth = 305 Meters, Receiver Depth = 305 Meters, Frequency = 2.5 Kilohertz



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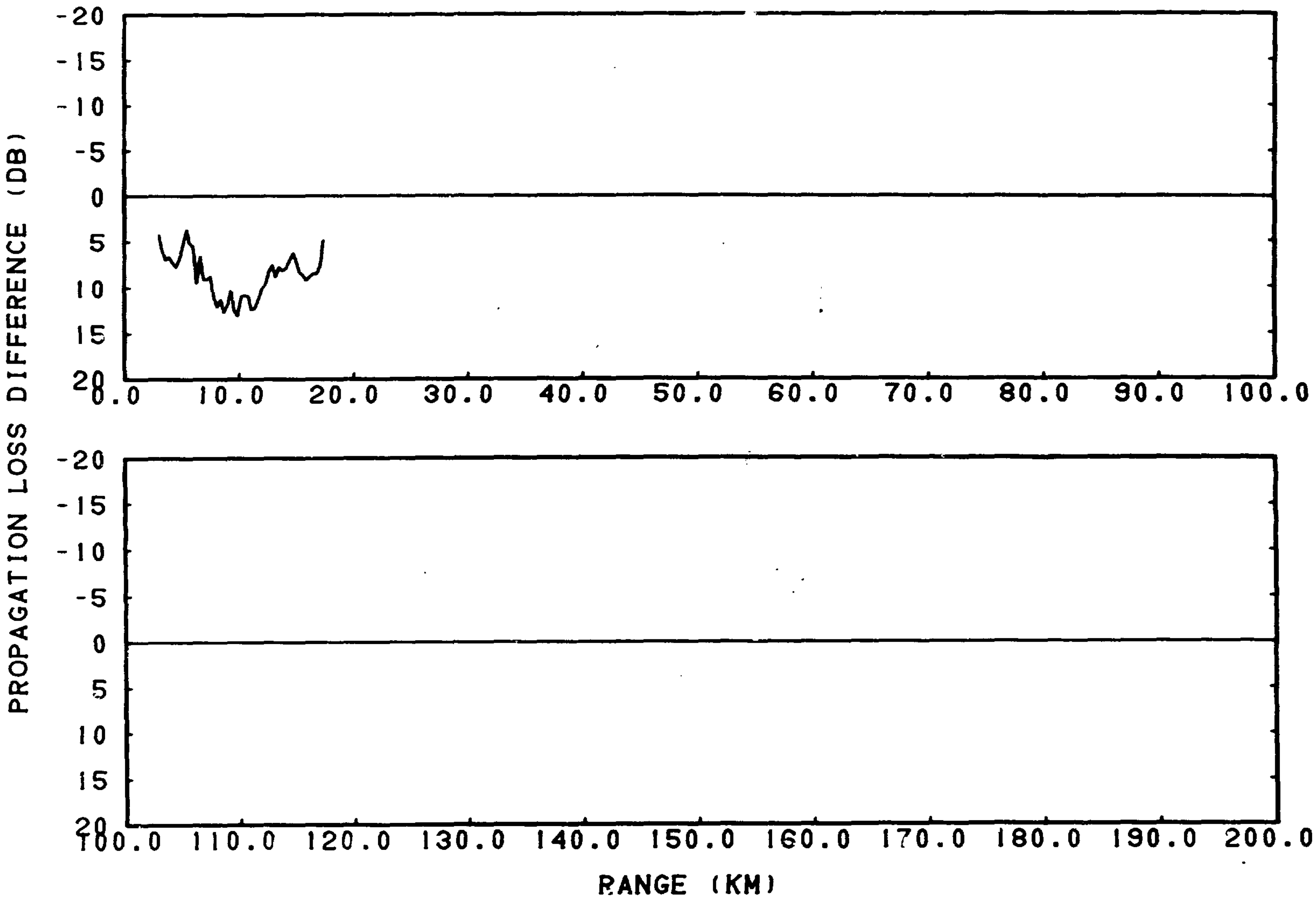
(C) Figure IIIH-82. RAYMODE Incoherent, Run 112B, Source Depth = 305 Meters, Receiver Depth = 305 Meters, Frequency = 2.5 Kilohertz



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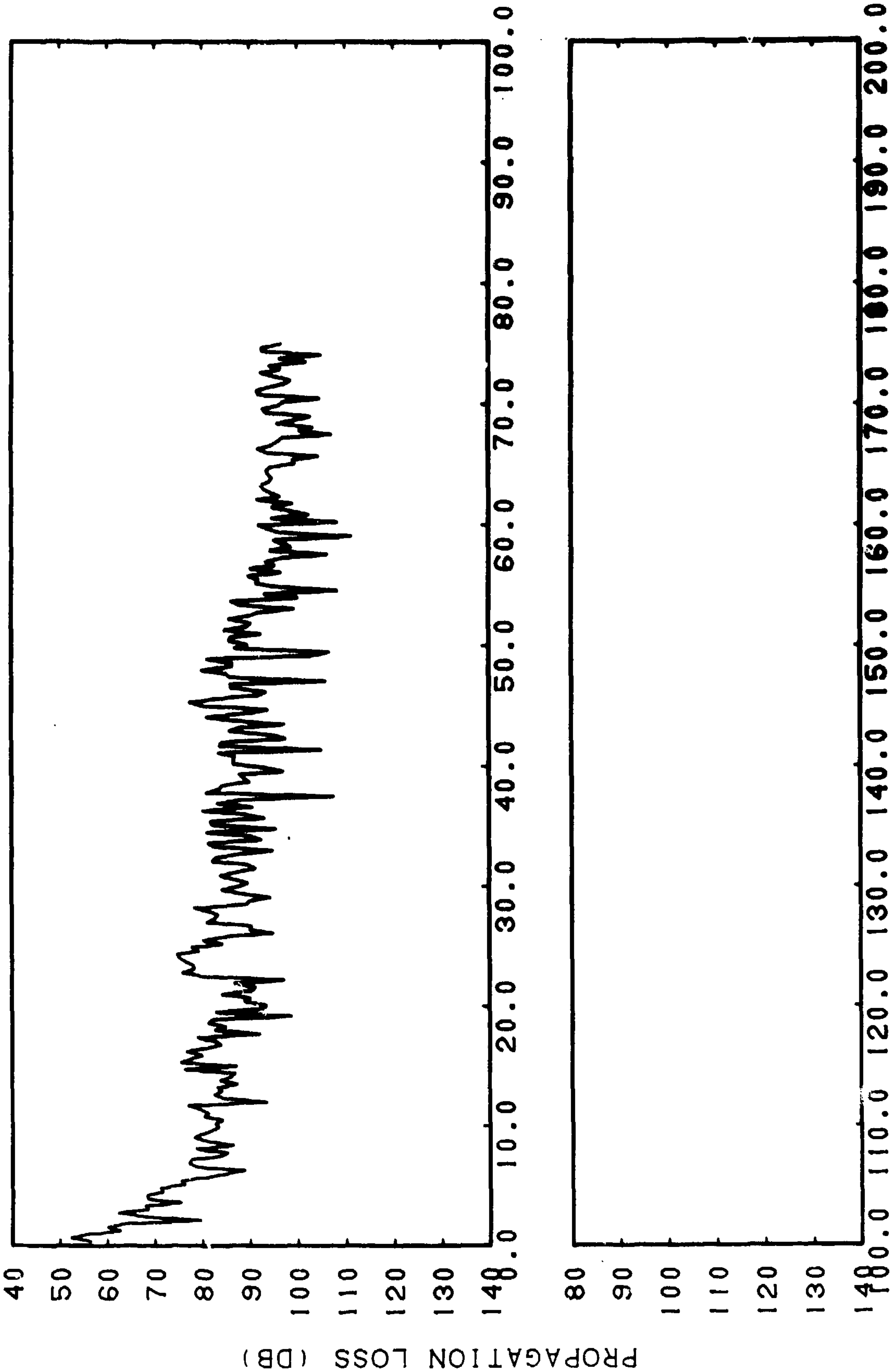
(C) Figure IIIH-83. RAYMODE Incoherent, Run 112B, Source Depth = 305 Meters, Receiver Depth = 305 Meters, Frequency = 2.5 Kilohertz, Subtracted from Smoothed Gulf of Alaska, Run 112B, Source Depth = 305 Meters, Receiver Depth = 305 Meters, Frequency = 2.5 Kilohertz



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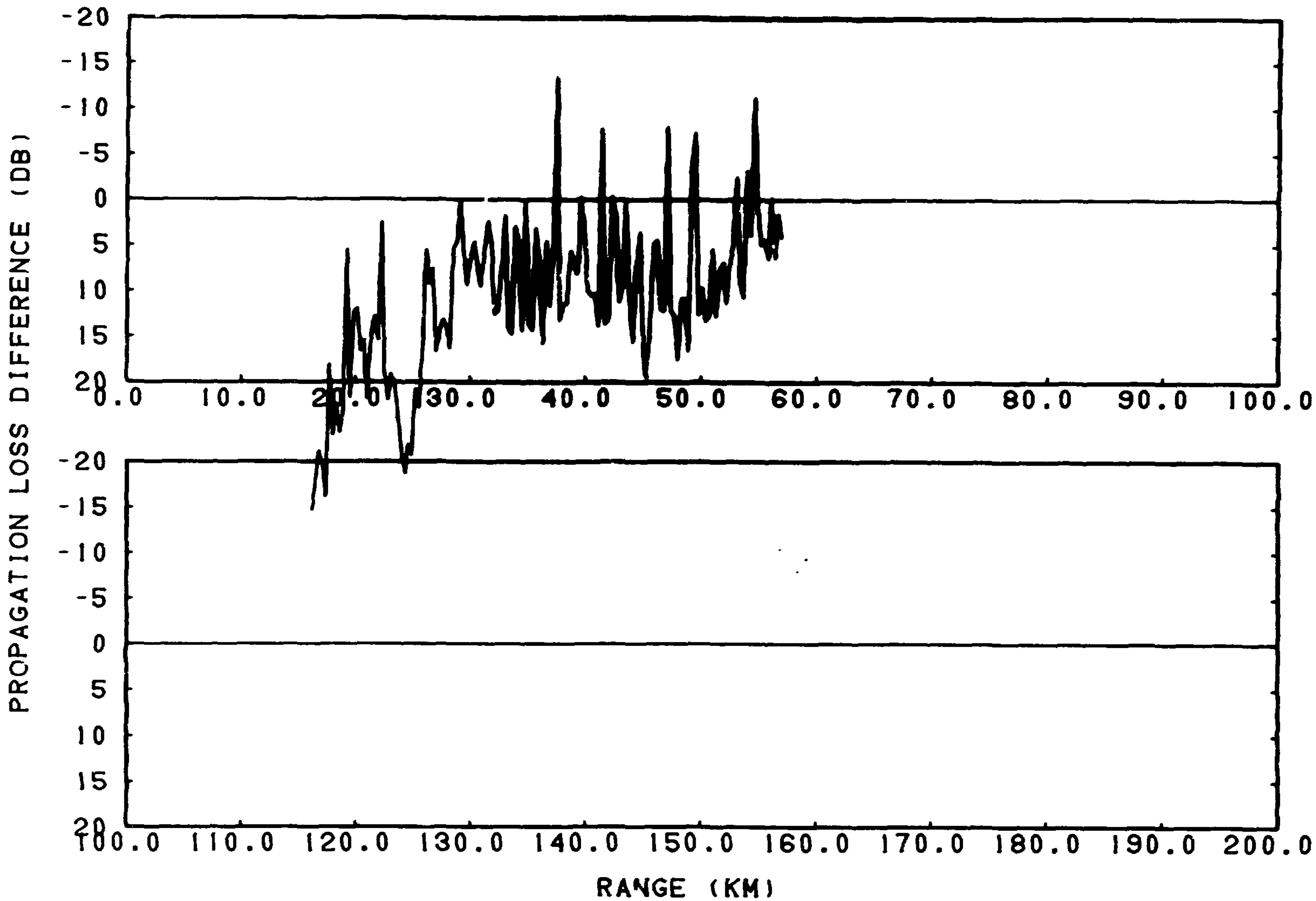
(C) Figure IIIH-84. RAYMODE Coherent, Run 112A, Source Depth = 306 Meters, Receiver Depth = 30.5 Meters, Frequency = 2.5 Kilohertz



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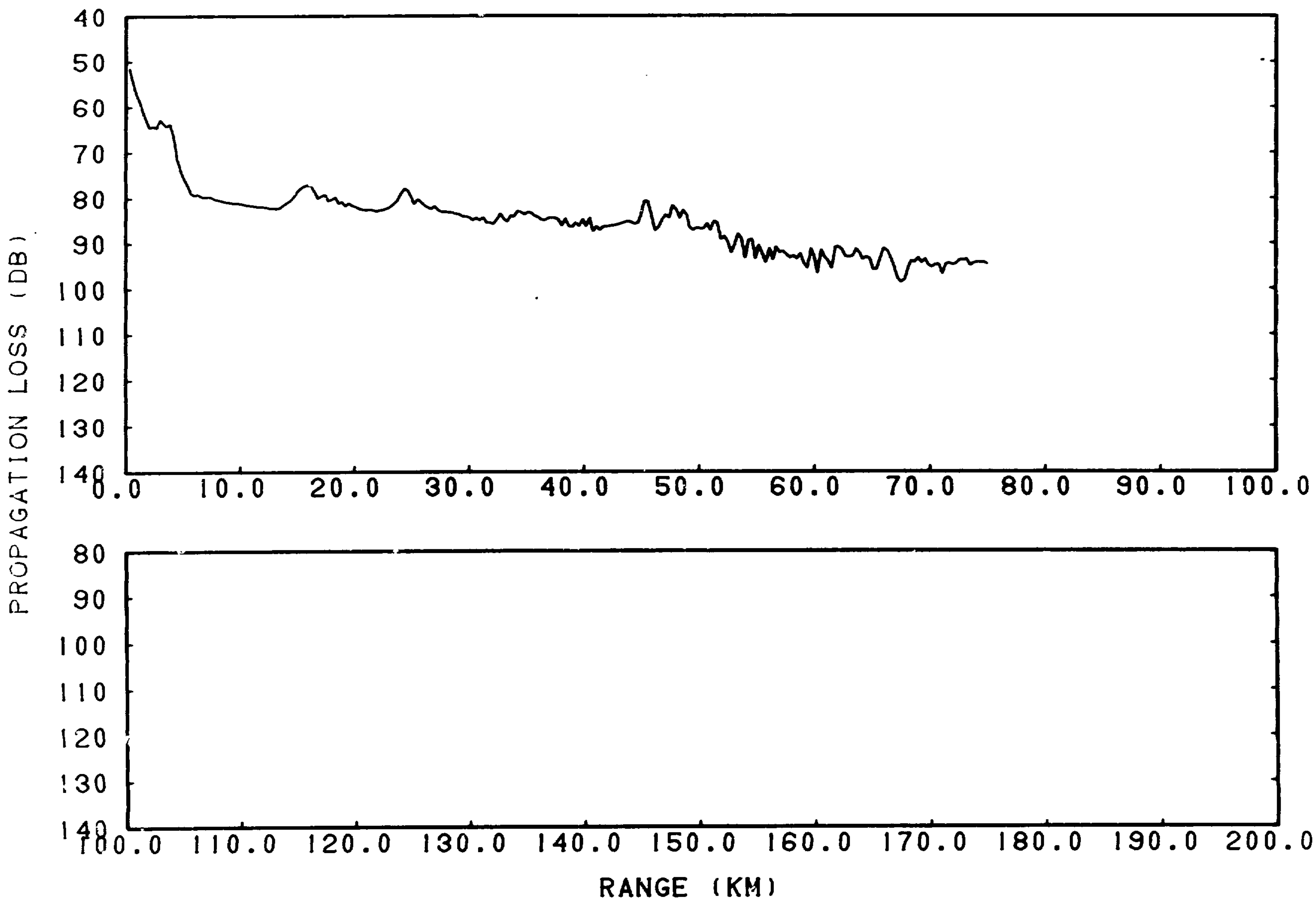
(C) Figure IIIH-85. RAYMODE Coherent, Run 112A, Source Depth = 305 Meters, Receiver Depth = 30.5 Meters, Frequency = 2.5 Kilohertz, Subtracted from Smoothed Gulf of Alaska, Run 112A, Source Depth = 305 Meters, Receiver Depth = 30.5 Meters, Frequency = 2.5 Kilohertz



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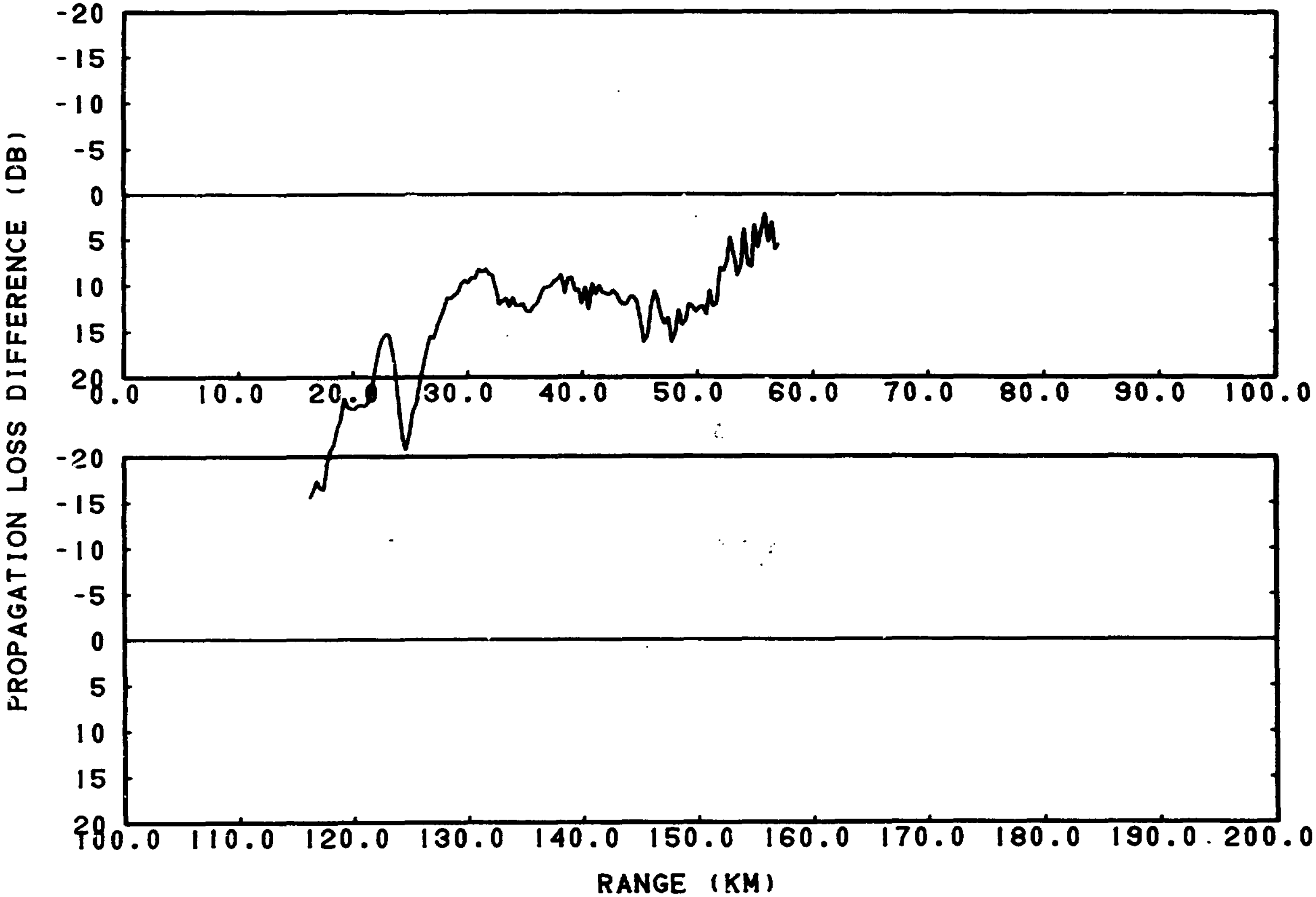
(C) Figure IIIH-86. RAYMODE Incoherent, Run 112A, Source Depth = 305 Meters, Receiver Depth = 30.5 Meters, Frequency = 2.5 Kilohertz



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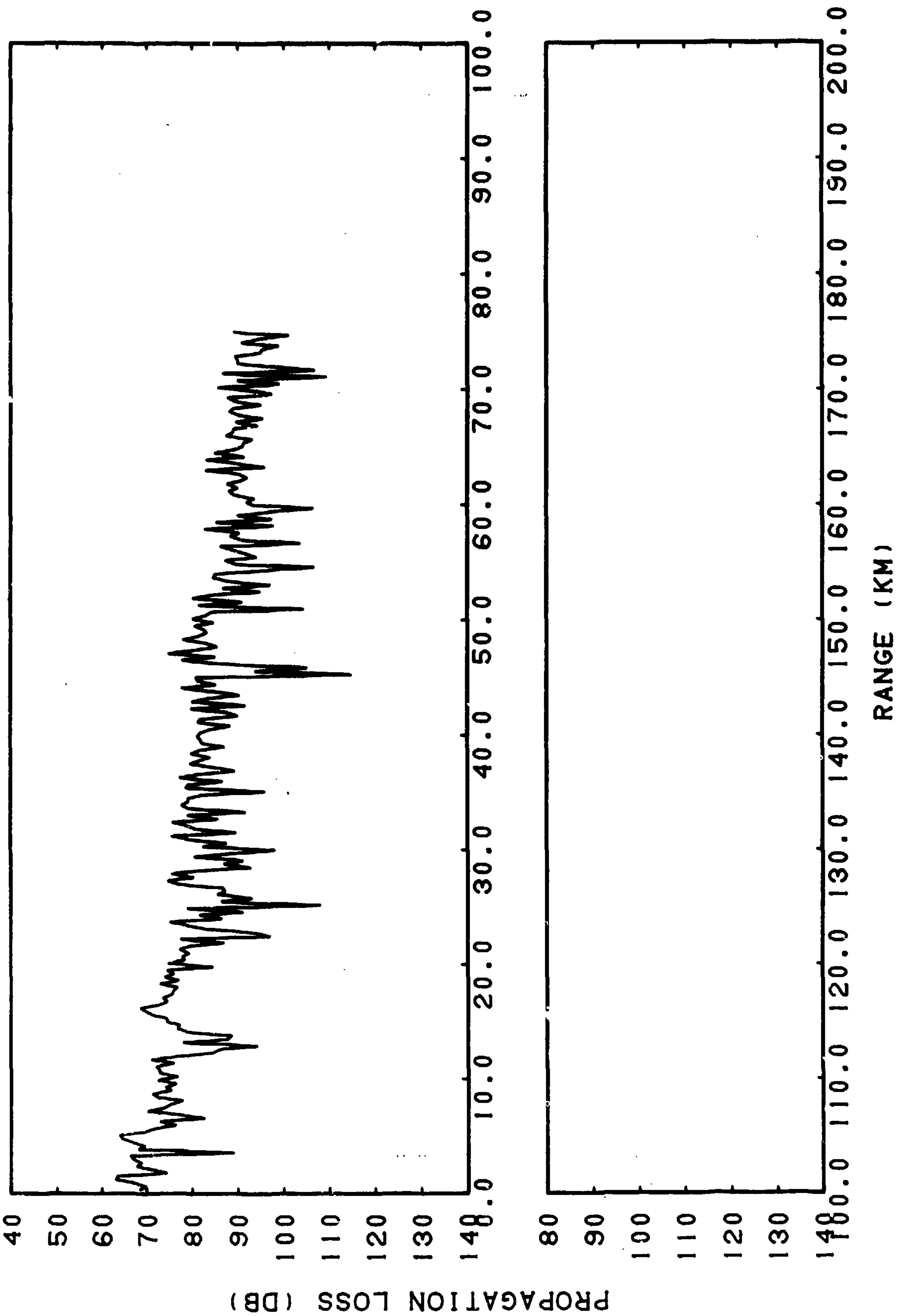
(C) Figure IIIH-87. RAYMODE Incoherent, Run 112A, Source Depth = 305 Meters, Receiver Depth = 30.5 Meters, Frequency = 2.5 Kilohertz, Subtracted from Smoothed Gulf of Alaska, Run 112A, Source Depth = 305 Meters, Receiver Depth = 30.5 Meters, Frequency = 2.5 Kilohertz



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(C) Figure IIIH-88. RAYMODE Coherent, Run 112A, Source Depth = 305 Meters, Receiver Depth = 305 Meters, Frequency = 2.5 Kilohertz

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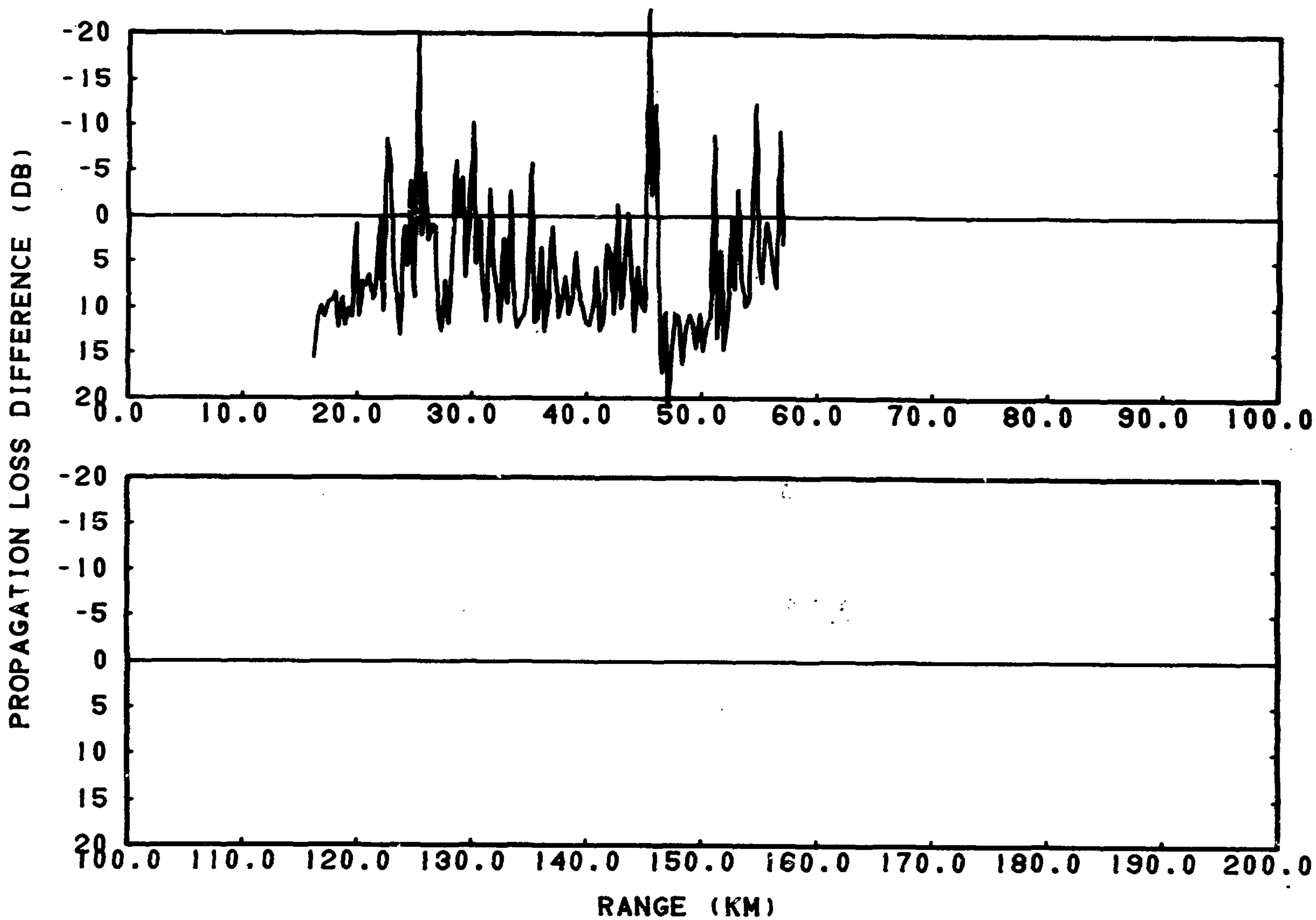

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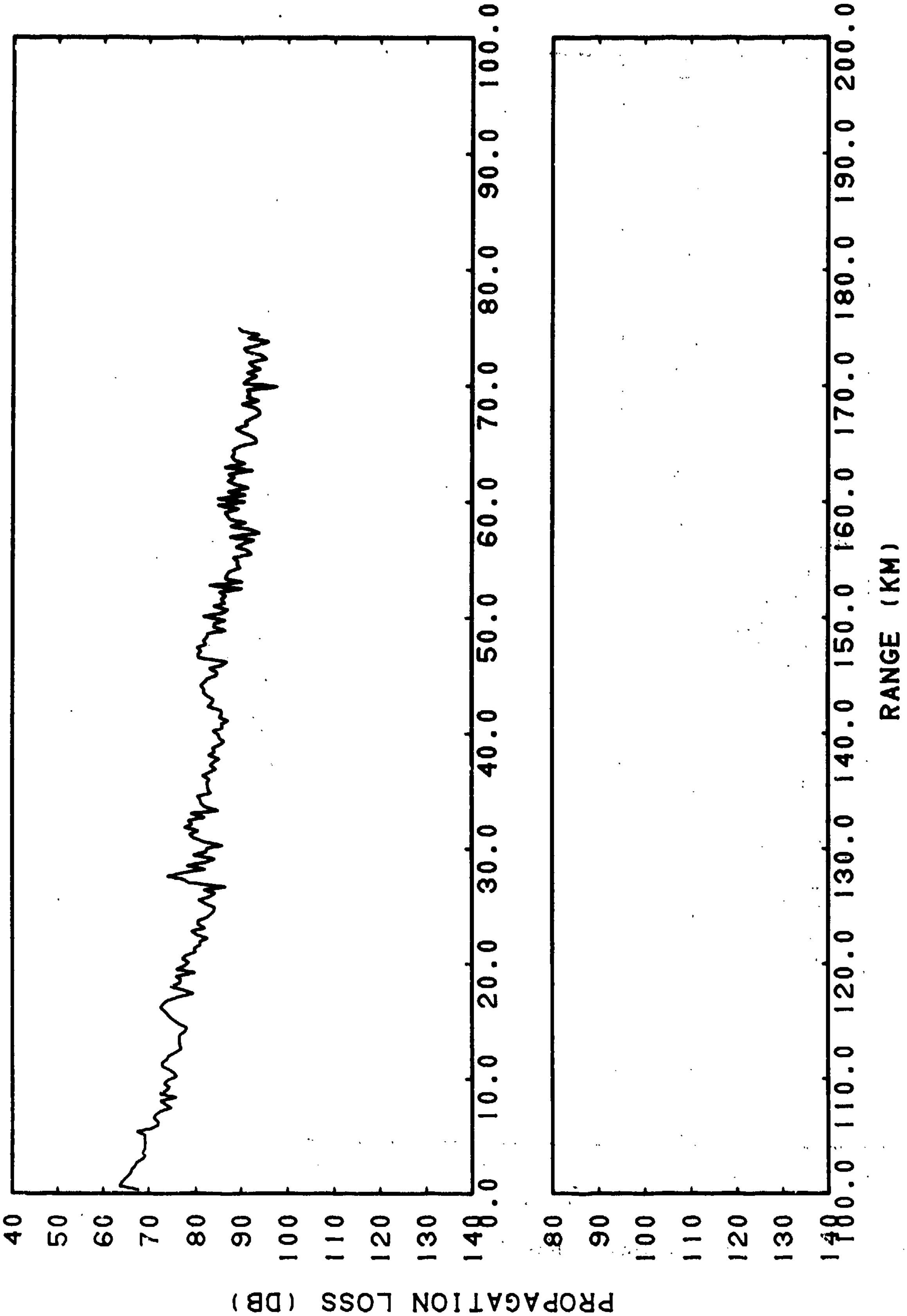
(C) Figure IIIH-89. RAYMODE Coherent, Run 112A, Source Depth = 305 Meters, Receiver Depth = 305 Meters, Frequency = 2.5 Kilohertz, Subtracted from Smoothed Gulf of Alaska, Run 112A, Source Depth = 305 Meters, Receiver Depth = 305 Meters, Frequency = 2.5 Kilohertz



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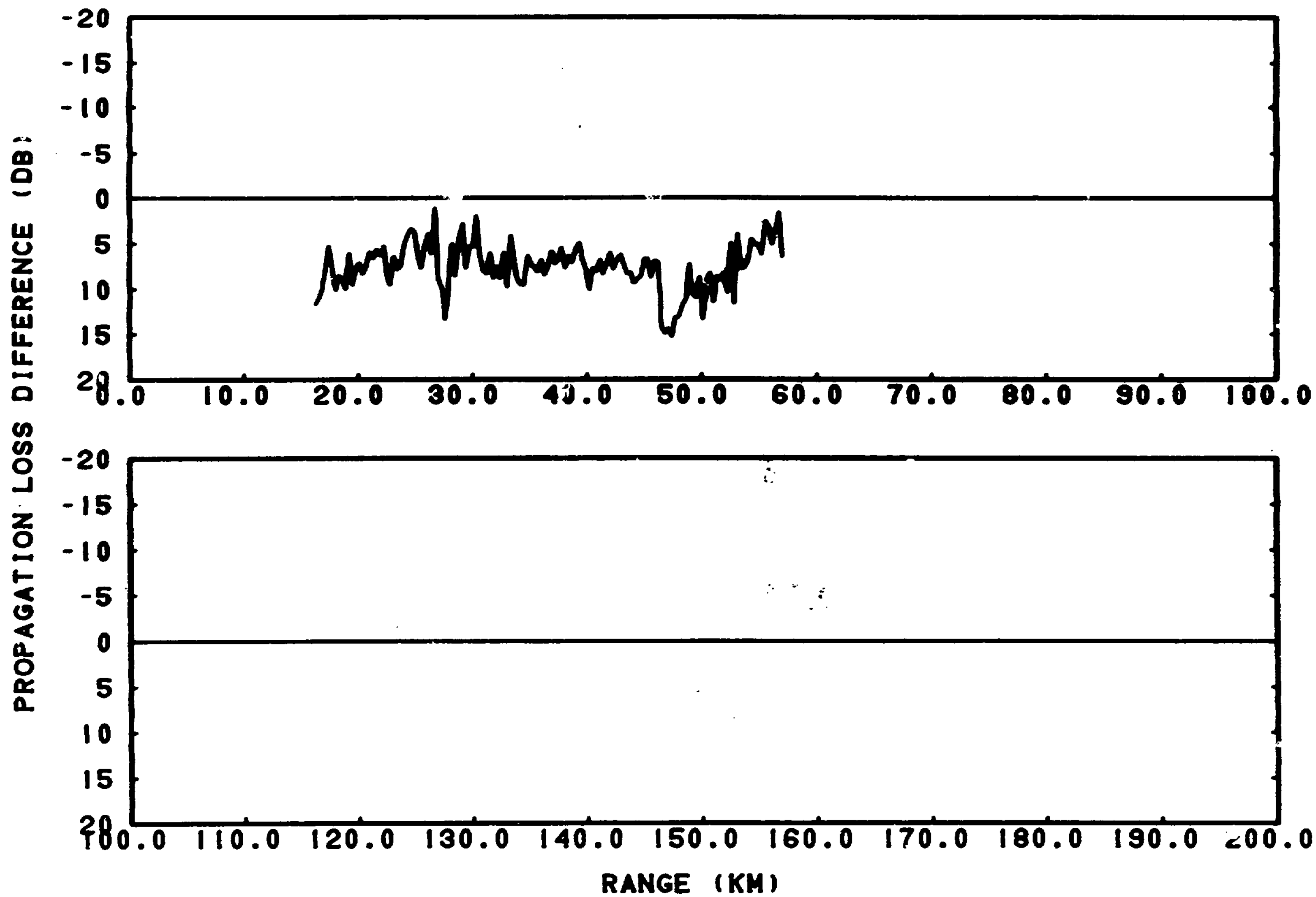
(C) Figure IIIH-90. RAYMODE Incoherent, Run 112A, Source Depth = 305 Meters, Receiver Depth = 305 Meters, Frequency = 2.5 Kilohertz



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(C) Figure IIIH-91. RAYMODE Incoherent, Run 112A, Source Depth = 305 Meters, Receiver Depth = 305 Meters, Frequency = 2.5 Kilohertz, Subtracted from Smoothed Gulf of Alaska, Run 112A, Source Depth = 305 Meters, Receiver Depth = 305 Meters, Frequency = 2.5 Kilohertz

DEPARTMENT OF THE NAVY
OFFICE OF NAVAL RESEARCH
800 NORTH QUINCY STREET
ARLINGTON, VA 22217-5660

IN REPLY REFER TO
5510/1
Ser 93/160
10 Mar 99

From: Chief of Naval Research
To: Commander, Naval Meteorology and Oceanography Command
1020 Balch Boulevard
Stennis Space Center MS 39529-5005

Subj: DECLASSIFICATION OF PARKA I AND PARKA II REPORTS

Ref: (a) CNMOC ltr 3140 Ser 5/110 of 12 Aug 97

Encl: (1) Listing of Known Classified PARKA Reports

1. In response to reference (a), the Chief of Naval Operations (N874) has reviewed a number of Pacific Acoustic Research Kaneohe-Alaska (PARKA) Experiment documents and has determined that all PARKA I and PARKA II reports may be declassified and marked as follows:

Classification changed to UNCLASSIFIED by authority of Chief of Naval Research letter Ser 93/160, 10 Mar 99.

DISTRIBUTION STATEMENT A: Approved for public release. Distribution is unlimited.

2. Enclosure (1) is a listing of known classified PARKA reports. The marking on those documents should be changed as noted in paragraph 1 above. When other PARKA I and PARKA II reports are identified, their markings should be changed and a copy of the title page and a notation of how many pages the document contained should be provided to Chief of Naval Research (ONR 93), 800 N. Quincy Street, Arlington, VA 22217-5660. This will enable me to maintain a master list of downgraded PARKA reports.

3. Questions may be directed to the undersigned on (703) 696-4619, DSN 426-4619.

Peggy Lambert

PEGGY LAMBERT
By direction

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The Acoustic Model Evaluation Committee (AMEC) Reports, Volume 2, The Evaluation of the Fact PL9D Transmission Loss Model, Book 3, Appendices E-H, September 1982, NORDA-35-VOL-2-BK-3, 428 pages
√ (DTIC # C034 020)

The Acoustic Model Evaluation Committee (AMEC) Reports, Volume 3, The Evaluation of the RAYMODE X Propagation Loss Model, Book 1, September 1982, NORDA-36-VOL-3-BK-1, 127 pages
√ (DTIC # C034 021)

The Acoustic Model Evaluation Committee (AMEC) Reports, Volume 3, TheEvaluation of the RAYMODE X Propagation Loss Model, Book 2, Appendices A-D, September 1982, NORDA-36-VOL-3-BK-2, 324 pages
√ (DTIC # C034 022)

The Acoustic Model Evaluation Committee (AMEC) Reports, Volume 3, The Evaluation of the RAYMODE X Propagation Loss Model, Book 3, Appendices E-H, September 1982, NORDA-36-VOL-3-BK-3, 388 pages
√ (DTIC # C034 023)